



U.S. Department of Energy

Livermore Site Office, Livermore, California 94550

Lawrence Livermore National Laboratory



University of California, Livermore, California 94550

UCRL-AR-220827-DRAFT

Draft Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300

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May 2006

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Environmental Protection Department

Environmental Restoration Division

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Certification

I certify that the work presented in this report was performed under my supervision. To the best of my knowledge, the data contained herein are true and accurate, and the work was performed in accordance with professional standards.

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Approval and Concurrence for the Five-Year Review for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300

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1. Introduction

The United States Department of Energy (DOE) has conducted a five-year review of the remedial actions implemented at the General Services Area (GSA) operable unit (OU) at Lawrence Livermore National Laboratory (LLNL) Site 300. DOE is the lead agency for environmental restoration at LLNL. The review documented in this report was conducted from November 2005 through February 2006. Parties providing analyses in support of the review include:

- U.S. DOE, Livermore Site Operations Office.
- LLNL, Environmental Restoration Division.
- Weiss Associates.

The purpose of a five-year review is to evaluate the implementation and performance of a remedy to determine whether the remedy will continue to be protective of human health and the environment. The five-year review report presents the methods, findings, and conclusions of the review. In addition, the five-year review identifies issues or deficiencies in the selected remedy, if any, and presents recommendations to address them. The format and content of this document is consistent with guidance issued by DOE (DOE, 2000a) and the U.S. Environmental Protection Agency (EPA) (EPA, 2001).

This is the second five-year review for the GSA OU. The first five-year review was completed in 2001 (Ferry, 2001). Although not required by statute, this review is considered a policy review because the remedial action will allow for unlimited use and unrestricted exposure upon completion, but will take longer than five years to complete. In accordance with DOE policy, the triggering action for the first review was the date of actual remedial action onsite construction, assumed to be the signature date, February 5, 1997, of the Final Record of Decision (ROD) for the GSA OU (DOE, 1997). Five-year reviews are conducted individually for the other OUs at Site 300 and will be performed five years after the completion of the final Remedial Design Reports.

The background and description of the GSA OU are presented in Section 3. The following paragraphs include the descriptions and status of the other OUs and areas where environmental restoration activities are occurring at Site 300. Many of these areas and OUs were included in the Interim Site-Wide ROD for Site 300 (DOE, 2001).

Building 834 OU - The Building 834 facilities have been in use since the late 1950s for experiments involving thermal cycling of weapons components. From 1962 to 1978, intermittent spills and piping leaks resulted in contamination of the subsurface with trichloroethylene (TCE) and silicone oils. Nitrate contamination in ground water results from septic-system effluent but may also have natural sources. Ground water and soil vapor extraction and treatment began in 1986 as treatability studies. Cleanup continued under an Interim ROD for the OU and later under the Interim Site-Wide ROD for Site 300 (DOE, 2001). DOE has periodically modified and expanded the extraction wellfield and upgraded the treatment facilities, and is conducting treatability studies to evaluate *in situ* biodegradation. Construction of the interim remedy was completed in 2004. The five-year review conducted for the Building 834 OU remedial action in

2001 determined that the interim remedy was effective and protective of human health and the environment (Ferry, 2002). The next five-year review for this OU is scheduled for 2007.

Pit 6 Landfill OU - From 1964 to 1973, waste was buried in nine unlined trenches and animal pits at the Pit 6 Landfill. Contaminants in the subsurface include volatile organic compounds (VOCs), tritium, nitrate, and perchlorate. In 1971, DOE excavated portions of the waste contaminated with depleted uranium. In 1997, a landfill cap was installed as a removal action to prevent infiltrating precipitation from further leaching contaminants from the waste. Because of decreasing TCE concentrations and tritium activities in ground water, the presence of TCE degradation products, and the short half-life of tritium (12.3 years), the selected interim remedy for TCE and tritium at the Pit 6 Landfill is monitored natural attenuation. DOE is evaluating the source, extent, and natural degradation of perchlorate and nitrate. The interim remedy for these contaminants in ground water is continued monitoring.

High Explosives Process Area OU - Surface spills from 1958 to 1986 resulted in the release of VOCs at the former Building 815 steam plant. High explosive compounds, nitrate, and perchlorate are present in the subsurface and are attributed to wastewater discharges to former unlined rinsewater lagoons. The High Explosives Burn Pits were capped in 1998. In 1999, DOE implemented a removal action to perform ground water extraction at the site boundary to prevent the TCE plume from migrating offsite. The selected interim remedy for this OU includes continued ground water extraction and treatment. The remedial design for the OU includes the operation of six ground water extraction and treatment systems. Buildout of the remedial action continues and construction completion is scheduled for 2007. A five-year review for this OU is scheduled for 2007.

Building 850 Firing Table - High explosives experiments have been conducted at the Building 850 Firing Table since 1958. Tritium was used in these experiments, primarily between 1963 and 1978. As a result of the dispersal of test assembly debris during explosions, surface soil was contaminated with metals, polychlorinated biphenyls (PCBs), dioxins, furans, high-explosive compounds, and depleted uranium. Leaching from firing table debris has resulted in tritium and depleted uranium contamination in subsurface soil and ground water. Nitrate has also been identified in ground water. PCB-contaminated shrapnel and debris was removed from the area around the firing table in 1998. The selected remedy for the Building 850 area includes excavation of the contaminated surface soil and a nearby sand pile as a final remedy and monitored natural attenuation of tritium in ground water as an interim remedy. DOE is currently evaluating alternate technologies to address the PCB-contaminated soil due to significant cost increases for offsite disposal of the soil. A five-year review for this OU is scheduled for 2009.

Pit 7 Landfill Complex - The Pit 3, 4, 5, and 7 Landfills are collectively designated the Pit 7 Landfill Complex. Firing table debris containing tritium, depleted uranium, and metals was placed in the pits in the 1950s through the 1980s. The Pit 4 and 7 Landfills were capped in 1992. Ongoing releases of contaminants to ground water are occurring. DOE has completed an area-specific Remedial Investigation/Feasibility Study (Taffet, 2005). A preferred remedy is presented in the Proposed Plan for Environmental Cleanup at the Pit 7 Complex (DOE, 2006). An interim remedy for the Pit 7 Complex will be selected in an Amendment to the Interim Site-Wide ROD in 2006. The interim remedy is scheduled for implementation in 2007.

Pit 2 Landfill - The Pit 2 Landfill was used from 1956 to 1960 to dispose of firing table debris and gravel. No unacceptable risk or hazard to human health or ecological receptors has been associated with the Pit 2 Landfill. Recent data indicate possible releases of depleted uranium from the landfill. The selected interim remedy for the Pit 2 Landfill is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill. Deficiencies in the selected remedy will be addressed in the upcoming Site-Wide Remediation Evaluation Summary Report.

Building 854 OU - TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid, primarily between 1967 and 1984. Other contaminants in ground water include nitrate and perchlorate. Some TCE-contaminated soil was excavated in 1983. PCB, dioxin, and furan contaminated soil was excavation in 2005. Treatability studies to assess VOC, nitrate, and perchlorate extraction and treatment began in 1999. The selected interim remedy for this OU includes ground water and soil vapor extraction and treatment. The remedial design for the OU includes the construction and operation of three ground water and one soil vapor extraction and treatment systems. Buildout of the remedial action continues and construction completion is scheduled for 2007. A five-year review for this OU is scheduled for 2008.

Building 832 Canyon OU - TCE was released to soil and ground water through leaks and discharges of heat-exchange fluid at Buildings 830 and 832 between the late 1950s and 1985. Nitrate and perchlorate are also present in ground water. In 1999, DOE began a treatability study to evaluate ground water and soil vapor extraction at Building 832. The selected interim remedy for this OU includes continued soil vapor and ground water extraction and treatment. The remedial design for the OU includes the construction and operation of four ground water and two soil vapor extraction and treatment systems. Buildout of the remedial action continues and construction completion is scheduled for 2007. A five-year review for this OU is scheduled for 2011.

Building 801 Dry Well and the Pit 8 Landfill - Waste fluid was discharged to a dry well located adjacent to Building 801D from the late 1950s to 1984, resulting in minor subsurface VOC contamination. The Pit 8 Landfill was used to dispose of debris from the Building 801 Firing Table until an earthen cover was installed in 1974. There is no evidence of a contaminant release from the landfill. The selected interim remedy for this area is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill.

Building 833 - TCE was used as a heat-exchange fluid in the Building 833 area from 1959 to 1982 and was released through spills and rinsewater disposal, resulting in minor VOC contamination of the shallow soil/bedrock and perched ground water. The selected interim remedy for this area is continued monitoring.

Building 845 Firing Table and Pit 9 Landfill - High explosives experiments were conducted at the Building 845 Firing Table from 1958 to 1963. Leaching from firing table debris resulted in minor contamination of subsurface soil with depleted uranium and high-explosive compounds. No ground water contamination has been detected. The Pit 9 Landfill was used to dispose of firing table debris generated at the Building 845 Firing Table. The debris buried in the pit may contain tritium, uranium, and/or high-explosive compounds. However, there is no evidence of a contaminant release from the Pit 9 Landfill. No unacceptable risk or hazard was identified in either area. The selected interim remedy for this

area is enhanced vadose zone and ground water monitoring to detect any future releases from the landfill.

Building 851 Firing Table – The Building 851 Firing Table has been used for high-explosives research since 1982. These experiments resulted in minor VOC, depleted uranium, metals, and high-explosives contamination in soil and ground water. No unacceptable risk or hazard was identified in this area. The selected interim remedy for this area is continued monitoring.

Advanced Test Accelerator (Building 865) - Solvents were used at this facility, and Freon-113 has been detected in the subsurface. DOE is currently investigating this area.

Building 812 – This facility has been in use since the 1960s. Gravel from the firing table was pushed into an adjacent ravine or to the side of the table. A Characterization Summary Report for this area was submitted in 2005 (Ferry and Holtzapple, 2005a). Depleted uranium has been identified as a contaminant of concern (COC) in soil and ground water. Perchlorate and nitrate were also identified as COCs in ground water. A treatability study is planned for the extraction and treatment of ground water while the CERCLA pathway for this area is negotiated.

Sandia Test Facility - From about 1959 to 1960, Sandia National Laboratories (Livermore) operated a small, temporary firing table at Site 300. The facility consisted of a portable building with other structures built into the hillside and surrounded by sandbags. The facility may have been used to test or store high explosives. A Characterization Summary Report for this area was submitted in 2005 (Ferry and Holtzapple, 2005b). The characterization data indicate no significant releases of contamination have occurred to the environment as a result of activities in this area. DOE has proposed No Further Action for the Sandia Test Site area.

2. Site Chronology

The following chronology summarizes important events relevant to environmental restoration in the GSA OU:

1955

- LLNL Site 300 was established as a DOE high-explosives test facility.

1960s/1970s

- Solvents from the craft shops were discharged to dry wells in the Central GSA.
- Volatile organic compound (VOC)-contaminated rinsewater was discharged to the ground surface at the Building 879 steam-cleaning/sink facility.
- VOC-contaminated shop debris was disposed in Eastern GSA trenches.

1970s/1980s

- Solvent spills from drum rack occurred.

1982

- Site investigations began in the GSA OU.

1990

- LLNL Site 300 was placed on the National Priorities List.

1991

- Ground water extraction and treatment began in the Eastern GSA as a removal action.

1992

- A Federal Facility Agreement for Site 300 was signed. The parties to the Agreement included DOE, the U.S. Environmental Protection Agency (EPA), the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB).

1993

- Ground water extraction and treatment began in the Central GSA as a removal action.

1994

- Soil vapor extraction and treatment began in the Central GSA as a removal action.

1994

- The Site-Wide Remedial Investigation report (Webster-Scholten, 1994) was issued.

1995

- A Feasibility Study for the GSA OU was issued (Rueth et al., 1995).

1996

- The Proposed Plan for Environmental Cleanup of the GSA OU issued (DOE, 1996).

1997

- A Record of Decision for the GSA OU signed.
- Ground water and soil vapor extraction and treatment began as a remedial action.

1998

- The Remedial Design document for the GSA OU was issued (Rueth et al., 1998).

1999

- The Phase I expansion of the Central GSA extraction wellfield was completed.

2001

- The Five-Year Review for the GSA OU was issued (Ferry et al., 2001).

2005

- The Phase II expansion of the Central GSA extraction wellfield was completed.

3. Background

3.1. Physical Characteristics

3.1.1. Site Description

LLNL Site 300 is a U.S. DOE experimental test facility operated by the University of California. It is located in the Eastern Altamont Hills 17 miles east of Livermore, California (Figure 1). At Site 300, DOE conducts research, development, and testing associated with high-explosive materials. During previous Site 300 operations, a number of contaminants were released to the environment. These releases occurred primarily from spills, leaking pipes, leaching from unlined landfills and pits, high-explosive test detonations, and disposal of waste fluids in lagoons and dry wells (sumps).

The GSA OU is located in the southeast corner of Site 300 (Figure 1). Within the GSA are a number of craft shops, storage buildings, and offices that support the research being conducted at Site 300. The GSA has been separated into the Central GSA and the Eastern GSA based on differences in hydrogeology and the distribution of environmental contaminants. The majority of structures are located in the Central GSA. The Eastern GSA contains a sewage treatment and adjacent overflow ponds. The offsite area adjacent to the GSA is sparsely populated and used for agriculture. The nearest major population center (Tracy, California) is 8.5 miles to the northeast.

There are no environmentally sensitive areas on Site 300 property within the GSA OU. However, the California Department of Fish and Game operates an ecological preserve immediately northeast of the GSA along Corral Hollow Creek. Administrative controls are in place to minimize any potential detrimental impacts on the preserve from the GSA cleanup, including managing of ground water treatment system discharges to prevent surface water from reaching the preserve during the summer months.

3.1.2. Hydrogeologic Setting

The vadose zone and three primary hydrostratigraphic units (HSUs) in the GSA OU are described below, from shallowest to deepest. A southwest-northeast oriented hydrogeologic cross-section through the GSA is presented in Figure 2.

3.1.2.1. Vadose (Unsaturated) Zone

The vadose zone in the western portion of the Central GSA is comprised of the unsaturated portion of the Quaternary alluvial terrace (Qt) silty clay, sand, and gravel deposits, and the underlying Tertiary Neroly Upper Blue Sandstone (Tnbs₂). These deposits are unsaturated to a depth of approximately 10 to 20 feet below ground surface (bgs). The vadose zone is contaminated with VOCs in the vicinity of the Building 875 former dry wells.

In the eastern portion of the Central GSA (near the sewage treatment pond) and the Eastern GSA, the vadose zone is comprised of the unsaturated portion of the Quaternary alluvial (Qal) silty clay, sand, and gravel deposits and the underlying Tertiary Neroly Lower Blue Sandstone (Tnbs₁). In the Eastern GSA, these deposits are unsaturated to a depth of approximately 10 to

15 feet below ground surface (bgs). There is no significant contamination present in unsaturated Qal and Tnbs₁ units in the Eastern GSA.

3.1.2.2. Saturated Zone

There are three primary HSUs in the GSA OU. An HSU consists of one or more stratigraphic intervals that comprise a water-bearing zone exhibiting similar hydraulic and geochemical properties. The three HSUs identified beneath the GSA include:

- Qt-Tnsc₁ HSU, a shallow water-bearing zone in the western portion of the Central GSA.
- Tnbs₁ HSU, a deeper regional aquifer within the western portion of the Central GSA.
- Qal-Tnbs₁ HSU, a shallow water-bearing zone within the eastern portion of the Central GSA and throughout the Eastern GSA.

In the western portion of the Central GSA, the shallow Qt-Tnsc₁ HSU includes saturated Qt deposits, and the Tnbs₂ sandstone and Tnsc₁ siltstone/claystone bedrock units that subcrop beneath the Qt. Unconfined ground water occurs in the Tnbs₂ sandstone. The Tnsc₁ siltstone/claystone primarily acts as an aquitard between the Qt-Tnsc₁ HSU and the deeper Tnbs₁ regional aquifer, but also contains variable saturation. The depth to ground water in the Qt-Tnsc₁ HSU is 10 to 20 ft bgs, and ground water flows toward the south and east at a velocity of 0.05 to 0.10 ft/day. A potentiometric surface elevation contour map for the Qt-Tnsc₁ HSU in the Central GSA is presented as Figure 3. The Tnbs₁ regional aquifer underlies the Qt-Tnsc₁ HSU in the western portion of the Central GSA and consists of Tnbs₁ sandstone bedrock that is hydraulically separate from the overlying Qt-Tnsc₁ HSU. The Tnbs₁ regional aquifer is separated into upper and lower units by a ten-foot thick claystone marker bed that exists throughout the southeast corner of Site 300. Depth to ground water in the Tnbs₁ HSU in this area varies from 12 to 100 feet bgs and ground water flows to the south-southeast. Ground water velocity in the Tnbs₁ regional aquifer is approximately 0.3 feet per day.

In the eastern portion of the Central GSA (near the sewage treatment pond) and throughout the Eastern GSA, the Qt deposits and the Tnbs₂ and Tnsc₁ bedrock units are not present. Qal deposits directly overlie the shallow Tnbs₁ bedrock that comprises the Qal-Tnbs₁ HSU in this area. In the Eastern GSA, the hydraulic conductivity of the alluvium is significantly greater than in the Qt and Tnbs₂ bedrock in the western part of the Central GSA. The depth to ground water in Qal-Tnbs₁ HSU is 10 to 15 ft bgs. Ground water in the Qal flows toward the east and north at a velocity of 0.5 to 3 feet per day; ground water flow in the Tnbs₁ is generally toward the south. A potentiometric surface elevation contour map for the Qal-Tnbs₁ HSU in the Eastern GSA is presented as Figure 4.

3.2. Land and Resource Use

Prior to DOE establishing Site 300 as remote testing facility in 1955, the area was used for cattle grazing. Site 300 is currently an operating facility, and will remain under DOE control for the reasonably anticipated future. Craft shops, storage buildings, and offices in the Central GSA are still used to support the research conducted at Site 300. Land in the Eastern GSA is undeveloped and is not used for LLNL programmatic activities. There are no active onsite

water-supply wells in the GSA. Two former onsite water-supply wells in the Central GSA were sealed and abandoned in 1988 and 1990 due to the detection of TCE in samples from these wells.

There are no planned modifications or proposed development of the offsite land adjacent to the GSA. Current offsite land use near the GSA includes cattle grazing, private residences, and an ecological preserve. Offsite, several private water-supply wells are in use for domestic and agricultural uses. These offsite wells are monitored regularly and no contamination from the GSA has been detected in these wells since 2001.

3.3. History of Contamination

The eight confirmed contaminant release sites in the GSA are shown on Figure 5 and listed below:

1. The Building 879 Steam-Cleaning/Sink facility.
2. Former dry well 875-S1.
3. Former dry well 875-S2.
4. A decommissioned solvent drum rack and underground solvent retention tank.
5. Former dry well 872-S.
6. Former dry well 873-S.
7. A former debris burial trench west of the sewage treatment pond in the Central GSA.
8. Several former debris burial trenches north of the sewage treatment overflow pond in the Eastern GSA.

Solvents containing VOCs were commonly used as degreasing agents in craft shops in the Central GSA. Rinse water from these operations was disposed of in dry wells. Typically, the dry wells in the Central GSA were gravel-filled pits 3 to 4 feet deep and 2 feet across. The dry wells were used until 1982 and were all excavated in 1983 to 1984.

In the Eastern GSA, various types of debris were disposed of in debris burial trenches during the 1960s and 1970s. Some of this debris was contaminated with small quantities of VOCs. Trenching of the debris burial area, interviews with former and present employees, and examination of aerial photographs indicate that the trenches contain primarily metal, ceramic, and glass debris from the craft shops.

3.4. Initial Response

DOE began environmental investigations in the GSA in 1982. Since then, over 100 monitor wells have been installed to characterize the vertical and horizontal extent of contamination throughout the GSA and to measure ground water elevations. Other site characterization methods included soil sampling, soil vapor surveys, hydraulic testing, colloidal borescope investigations, and geophysical surveys. Test pits were also used to determine the extent of burial trenches and contamination in the Eastern GSA.

Pre-ROD remediation activities at the GSA included:

- Excavating and backfilling all dry wells.
- Sealing and abandoning impacted or threatened water-supply wells.
- Removal actions to begin ground water and soil vapor extraction and treatment.

3.5. Contaminants of Concern

The primary contaminant of concern found in ground water and soil at the GSA is TCE, comprising approximately 90% of the total VOCs. TCE is a suspected human carcinogen. Other contaminants of concern identified in the GSA include tetrachloroethylene (PCE), cis-1,2-dichloroethylene (DCE), 1,1-DCE, 1,1,1-trichloroethane (TCA), acetone, benzene, toluene, xylenes, bromodichloromethane, chloroform, trichlorofluoromethane (Freon 11), and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113).

In the Central GSA, the highest preremediation concentration of TCE in soil was 360 milligrams per kilogram (mg/kg), detected below the Building 875 dry wells. The preremediation concentration of total VOCs in ground water was approximately 272,000 micrograms per liter ($\mu\text{g/L}$). The 2005 maximum total VOC concentration was 547 $\mu\text{g/L}$ (see Section 7.4). Globules of TCE (a Dense Non-Aqueous Phase Liquid, or DNAPL) were observed in some ground water samples. The baseline human health risk assessment conducted in 1991 estimated a maximum excess carcinogenic risk of 7×10^{-2} if ground water from a hypothetical water-supply well located at the site boundary near the Building 875 dry wells were to be ingested over a 70-yr period (risk values below 10^{-6} are considered protective). The corresponding noncarcinogenic hazard index was 560 (hazard indices below 1 are considered protective). The baseline risk assessment also estimated an excess cancer risk to onsite workers from TCE vapors migrating into Building 875 of 1×10^{-5} .

In the Eastern GSA, the highest preremediation concentration of total VOCs detected in shallow ground water near the debris burial trench was approximately 74 $\mu\text{g/L}$. Prior to the start of remediation, the plume of TCE in ground water exceeding the Maximum Contaminant Level (MCL) of 5 $\mu\text{g/L}$ extended approximately 4,200 feet offsite. Very low concentrations of VOCs (maximum of 0.017 mg/kg) were detected in the vadose zone beneath the debris trenches in the Eastern GSA. The 1991 baseline human health risk assessment estimated an excess carcinogenic risk of 5×10^{-5} for ingesting ground water from a hypothetical water-supply well located at the site boundary near the debris burial trench. The risk associated with potential use of contaminated ground water at two offsite wells (CDF-1 and SR-1) was approximately 10^{-5} . No unacceptable risk or hazard was associated with potential exposure to VOCs in surface or subsurface soil. As discussed in Section 7.4.1.2. below, soil vapor extraction has contributed to reducing the excess cancer risk due to inhalation of VOC vapors migrating into Building 875 from 1×10^{-5} prior to remediation to 9.5×10^{-7} in 2000. Inhalation risk within Building 875 is no longer of concern.

3.6. Summary of Basis for Taking Action

Remedial actions were initiated in the GSA OU to address unacceptable human health risks associated with subsurface contamination at the GSA OU including: (1) potential ingestion of

ground water containing VOCs at concentrations exceeding drinking water MCLs, and (2) onsite worker inhalation exposure to TCE volatilizing from the subsurface soil to indoor air within Building 875. The remedial actions were also initiated to restore the beneficial uses of ground water in this area. The remedial action objectives for the GSA cleanup are discussed in Section 4.1.

4. Remedial Actions

4.1. Remedy Selection

The remedies selected for the GSA OU are intended to achieve the following Remedial Action Objectives:

Protection of Human Health:

- Prevent human ingestion of the ground water containing VOC concentrations (single carcinogen) above the State and Federal drinking water MCLs, a cumulative excess cancer risk (all carcinogens) greater than 10^{-6} , and a cumulative hazard index (all noncarcinogens) greater than 1.
- Prevent human inhalation of VOCs in vapor in concentrations above those that pose an excess cancer risk of 10^{-6} .

Protection of the Environment:

- Restore water quality, at a minimum, to water quality objectives that are protective of beneficial uses (i.e., MCLs).

The cleanup standard for ground water in the GSA OU is to reduce VOC concentrations to MCLs in all impacted ground water. VOCs in the vadose (unsaturated) zone will be remediated to the extent technically and economically feasible to minimize further degradation of the ground water by contaminants in the vadose zone. The vadose zone cleanup will be completed when it is demonstrated that: (1) VOCs remaining in the vadose zone no longer cause concentrations in the leachate to exceed the ground water cleanup standards, based on an interpretation of soil vapor data using an appropriate vadose zone model, and (2) VOCs have been removed to the extent technically and economically feasible to meet the ground water cleanup levels sooner, more cost-effectively, and more reliably. Another cleanup standard is to mitigate the excess cancer risk from inhalation of indoor air within Building 875 caused by VOCs migrating into the building from the subsurface.

The remedies for the GSA were selected based on their capacity to contain contaminant sources, prevent further plume migration, remove contaminant mass from the subsurface, and protect human health and the environment both onsite and offsite. In the remedial design phase, DOE considered hydrogeologic factors, contaminant characteristics, available remedial technologies, and effective performance monitoring techniques. The selected remedy for the GSA consists of:

- Ground water extraction and treatment in the Central GSA.
- Soil vapor extraction and treatment at the Building 875 dry well area in the Central GSA.

- Ground water extraction and treatment in the Eastern GSA.
- Regular ground water and soil vapor monitoring.
- Institutional controls, such as access/land-use restrictions and measures to prevent use of contaminated ground water.

4.2. Remedy Implementation

Sections 4.2.1 and 4.2.2 present a summary of the actions DOE has taken to implement the selected remedy in the GSA OU, and also describe any significant modifications to the remedy since the Final ROD (DOE, 1997) and Remedial Design (Rueth et al., 1998) documents for the GSA OU. Information on the performance of the remedy and the current concentrations and distribution of contamination is included in Section 7.4.

4.2.1. Central GSA

The Central GSA remediation system consists of ground water and soil vapor extraction and treatment as described in Sections 4.2.1.1. and 4.2.2.2. A map of the Central GSA, showing the locations of monitoring and extraction wells and treatment facilities is presented in Figure 6.

4.2.1.1. Ground Water

Ground water cleanup began in the Central GSA in 1993 using four extraction wells at the Building 875 dry well release area. The ROD and Remedial Design documents included plans to evaluate expansion of the shallow aquifer ground water extraction wellfield to include other contaminant sources and the downgradient extent of the VOC plume. Three extraction wells were added in 1999 (the Phase I wellfield expansion). Two of these extraction wells were installed at the Building 872 and Building 873 dry well VOC release sites (wells W-872-02 and W-873-07, respectively). The third well (W-7O) was installed hydraulically downgradient from the Building 875 dry well release area.

DOE presented a Phase II wellfield expansion work plan in 2000. With regulatory concurrence, the Phase II plan screened out six potential extraction wells that had been included in the remedial design (W-873-06, W-7S, W-7F, W-7T, W-7Q, and W-875-03), due to low contaminant concentrations and/or low well yields. The Phase II plan initially proposed the conversion of monitoring wells W-7R and W-7P to extraction wells. However, during the previous five-year review (2001), W-7P was screened out as an extraction well because of decreasing VOC concentrations in the Tnbs₁ HSU regional aquifer and the potential risk of drawing contaminants downward into the Tnbs₁ HSU from the overlying Qal HSU by pumping this well. The 2001 review also stated that DOE would reconsider extraction from well W-7P if VOC concentrations in the Tnbs₁ HSU regional aquifer did not continue to decline.

Since the last five-year review, VOC concentrations in samples of Tnbs₁ ground water collected from well W-7P have fluctuated from approximately 10 to 20 µg/L. The overall trend of total VOC concentrations in this well has been relatively stable over time. Therefore, DOE began pumping from well W-7P in 2005 to remove VOCs from Tnbs₁ ground water. Well W-7P is pumped at very low flow rates to prevent drawing contamination in Qal ground water into the Tnbs₁. Because well W-7P is screened over only 9 feet in the uppermost portion of the Tnbs₁

and ground water elevation data indicate W-7P is hydraulically connected to the Qal ground water in this area, low-flow pumping of W-7P should not result in further contamination of Tnbs₁ ground water. VOC concentrations and water levels in well W-7P and surrounding wells are monitored closely.

The Phase II expansion of the Central GSA extraction wellfield was completed in September 2005. New ground water extraction wells W-7R and W-7P began pumping in May and October 2005, respectively. Contaminated ground water is currently extracted from eight wells (W-7I, W-875-07, W-875-08, W-873-07, W-872-02, W-7O, W-7P, and W-7R). The current ground water extraction and treatment system configuration includes particulate filtration to remove sediment, air stripping to remove VOCs from extracted water, and granular activated carbon (GAC) to treat vapor effluent from the air stripper. Treated ground water is discharged to the surrounding natural vegetation using misting towers.

4.2.1.2. Vadose Zone

In July 1994, DOE began soil vapor extraction at the Building 875 dry well contaminant source area as a removal action. The soil vapor extraction wellfield and treatment system described in the GSA ROD and Remedial Design documents is fully implemented. Wells W-7I, W-875-07, W-875-08, and W-875-10 are used to extract soil vapor and W-875-09, W-875-11 and W-875-15 are currently used as passive air inlet wells. Simultaneous ground water extraction in the vicinity lowers the elevation of the ground water surface and maximizes the volume of unsaturated soil influenced by vapor extraction. Extraction well W-7I was discontinued in November 2005 due to the lack of flow. Additional vacuum was applied to the remaining wells (W-875-07, W-875-08, and W-875-10) to increase soil vapor rates and ground water yields.

The current soil vapor treatment system consists of a water knockout chamber, a rotary vane blower, and four 140-pound (lb) vapor-phase GAC columns arranged in series. Treated vapors are discharged to the atmosphere under permit from the San Joaquin Valley Unified Air Pollution Control District.

4.2.2. Eastern GSA

DOE began ground water remediation at the Eastern GSA in 1991 as a removal action and continued as a remedial action after the GSA ROD. An offsite ground water extraction and treatment facility was included in the remedial design. However, since the existing extraction configuration has been extremely successful in controlling offsite contaminant migration, this offsite facility was determined not to be needed. The regulatory agencies concurred with the decision not to install this facility.

Currently, contaminated ground water is extracted from the Qal portion of the Qal-Tnbs₁ HSU using three wells yielding approximately 15 gpm each. Initially, air sparging was used to treat extracted ground water, but a treatability study conducted in 1995-1996 indicated that treatment using aqueous-phase GAC was a simpler and more efficient technology at the site, and a GAC system was installed in 1997. The current treatment configuration includes particulate filtration, contaminant adsorption by aqueous-phase GAC using three 1,000-lb vessels arranged in series, and surface discharge to Corral Hollow Creek. The locations of ground water monitoring and extraction wells and treatment facility are shown in Figure 7.

4.3. System Operations/Operation and Maintenance

In general, the three extraction and treatment systems are operating as designed and no significant operations, performance, maintenance, or cost issues were identified during the review. All required documentation is in place, and treatment system operations and maintenance (O&M) activities are consistent with established procedures and protocols.

O&M procedures are contained in the following documents:

- Health and Safety Plan, Quality Assurance/Quality Control Plan, Compliance Monitoring Plan, and Contingency Plan for the GSA OU, contained within the Remedial Design document (Rueth et al., 1998).
- Operations and Maintenance Manual, Volume VI: Central General Services Area Vapor and Ground Water Treatment Facilities (Daily, 2004).
- Eastern GSA Treatment Facility Operations Checklist (LLNL, 1999).
- Central GSA: Substantive Requirements and the Monitoring and Reporting Program issued by the California RWQCB and the Permit to Operate issued by the San Joaquin Valley Unified Air Pollution Control District.
- Eastern GSA: Substantive Requirements and the Monitoring and Reporting Program issued by the RWQCB.

Monitoring and optimizing the performance and efficiency of the three extraction and treatment systems comprises a large portion of the O&M activities. Extracted ground water is sampled at multiple points during the treatment process to ensure compliance with discharge requirements. Treatment system parameters such as pressure, flow, and temperature are recorded weekly to anticipate potential mechanical problems. Monitor and extraction wells are sampled per the requirements of the GSA Compliance Monitoring Plan (Rueth et al., 1998) and Substantive Requirements. Semi-annual reports submitted to the regulatory agencies document all analytic results, O&M activities, and system performance data. Routine maintenance is performed on the monitor and extraction wells as needed.

The major O&M activity at the Central GSA ground water treatment facility is to ensure maximum operating efficiency of the air stripper. The internal air pressure within the air stripper is closely monitored. When this pressure reaches a pre-determined point (indicating buildup of scaling within the packing elements), the system is overhauled to ensure maximum efficiency of VOC removal from extracted ground water. Other O&M activities include injecting anti-scaling compounds, removing iron oxide buildup, maintaining remote computer access and data collection capabilities, protecting the unit from freezing in cold weather, and periodically replacing spent vapor-phase GAC.

The major O&M activities at the Central GSA soil vapor treatment facility are monitoring the performance of the system and replacing spent vapor-phase GAC. The vapors treated by the primary GAC vessel (the first of four in series) are tested regularly for VOC breakthrough. When breakthrough occurs in the effluent of the primary vessel, the effluent of the secondary vessel is tested until breakthrough occurs. Upon VOC breakthrough from the secondary vessel, both the primary and secondary GAC vessels are replaced. Other O&M issues include ensuring

the temperature within the GAC drums remains within the optimal range and optimizing the performance of the soil vapor extraction and ambient air injection wells.

DOE's major O&M activity at the Eastern GSA ground water treatment facility is replacing the 3,000 lbs of aqueous-phase GAC. The extracted ground water treated by the primary GAC vessel (the first of three in series) is sampled and analyzed regularly for VOCs. When VOCs break through the primary vessel, the effluent of the secondary vessel is tested until breakthrough occurs. Upon breakthrough from the secondary vessel, the GAC in both the primary and secondary vessels is replaced.

The ground water and soil vapor extraction and treatment systems in the Central GSA have consistently operated in compliance with all permits and requirements. The Eastern GSA ground water extraction and treatment system has also been in compliance with the exception that TCE was detected in the effluent slightly above the detection limit ($0.5 \mu\text{g/L}$) in February 2001, November 2002, and February 2004. The causes of the contaminant breakthrough were quickly identified and appropriate corrective actions were taken (replacement of aqueous-phase GAC). No regulatory action was taken.

The budgeted and actual costs associated with the management, investigation, testing, modeling, design, construction, and O&M of the environmental remediation activities within the GSA are tracked closely. The GSA OU has consistently operated well below the estimated annual operating costs reported in the ROD. Table 1 presents the actual costs for the last five fiscal years, 2001 through 2005.

5. Progress Since Last Review

This section describes the Protectiveness Statement and recommendations and follow-up actions from the 2001 GSA Five-Year Review (Ferry et al., 2001). It also describes the status of the actions recommended in this previous review.

5.1. Protectiveness Statement From Last Review

The 2001 GSA Five-Year Review indicated that the remedy for the GSA OU was protective of human health and the environment. The Health and Safety Plan and the Contingency Plan are in place, sufficient to control risks, and properly implemented. Ground water and soil vapor extraction and treatment are effectively controlling the migration of contaminants, and reducing contaminant concentrations in the subsurface as needed to meet cleanup standards in the time frame anticipated at the time of the ROD. Institutional controls are in place to prevent use of contaminated ground water.

No deficiencies in the remedy were identified during the previous five-year review conducted in 2001.

5.2. Recommendations and Follow-up Actions from the 2001 Five-Year Review

The following recommendations were developed during the five-year review process in 2001:

1. A high priority should be given to optimizing ground water and soil vapor extraction well placement and pumping rates to maximize contaminant capture within the existing wellfields and shorten the time required to reach cleanup standards.
2. Additional ground water extraction wells located north of Building 875 should be considered. Although VOC concentrations in ground water in this area are relatively low (maximum of 46 $\mu\text{g/L}$), the lateral extent of this plume is limited and ground water extraction may accelerate achievement of cleanup standards throughout the GSA.
3. Contaminants in the regional aquifer in the Central GSA should be closely monitored, but extraction should be considered only if data indicate that the current declining concentration trend does not continue.
4. In the Eastern GSA, DOE should consider the possibility of undetected VOC mass if ground water remediation does not continue its current progress toward achieving cleanup standards.

If DOE and the regulatory agencies agree to incorporate any or all of these recommendations, implementation milestones can be added to the schedule in the Federal Facility Agreement for Site 300, and/or administered less formally by inclusion in the minutes of the Remedial Project Manager's monthly meetings.

No other follow-up actions were identified in the 2001 five-year review.

5.3. Results of Implemented Actions

The status of actions taken in response to the recommendations listed in Section 5.2 are as follows:

1. During 2005, wells W-7R and W-7P were added to the Central GSA extraction wellfield to increase contaminant mass removal and capture as part the Phase II wellfield expansion. A rebound test was conducted in 2003 and 2004 to evaluate the magnitude of the remaining VOC source in the vadose zone. The Phase II wellfield expansion and the SVE rebound test are discussed in Section 6.5. VOC data from ground water and soil vapor extraction wells are used to adjust system operations to optimize their effectiveness in removing contaminant mass and reducing concentrations.
2. Since 2001, VOC concentrations in the northern plume area have continued to gradually decline and the extent of the plume is generally stable. For this reason, no ground water extraction has occurred in this area to date. VOC concentrations in the northern plume area are discussed further in Section 6.5.
3. Since the last five-year review, total VOCs have been detected in only 4 of the 15 wells screened in the Tnbs₁ regional aquifer in the Central GSA. Tnbs₁ well W-7P was added to the Central GSA extraction wellfield in 2005. Due to the continued very low VOC

concentrations detected in the regional aquifer, additional extraction from this aquifer has not been considered. Further detail regarding VOC concentrations in the Tnbs₁ regional aquifer is discussed in Section 7.4.

4. By 2005, the Eastern GSA remediation system has successfully reduced VOC concentrations in ground water to meet the MCL ground water cleanup standards. As a result, the ground water extraction and treatment system will be shut down and monitoring will be conducted to determine if VOC concentrations rebound above cleanup standards. Additional details are provided in Section 7.5.

5.4. Status of Other Prior Issues

There are no other prior issues.

6. Five-Year Review Process

The five-year review of the GSA OU at LLNL Site 300 was led by Claire Holtzapple, Site 300 Remedial Project Manager for the DOE/NNSA-Livermore Site Office. The following team members assisted in the review:

- William Daily, Engineer, LLNL
- Valerie Dibley, Deputy Project Leader, LLNL
- Vic Madrid, Environmental Scientist, LLNL
- John Valett, Geologist, Weiss Associates
- Zafer Demir, Hydrogeological Engineer, LLNL.

This five-year review consisted of examining relevant project documents and site data:

- Final Site-Wide Remedial Investigation for Lawrence Livermore National Laboratory Site 300 (Webster-Scholten et al., 1994).
- Final Feasibility Study for the General Services Area at Lawrence Livermore National Laboratory Site 300 (Rueth and Berry, 1995).
- Proposed Plan for Remediation of the Lawrence Livermore National Laboratory Site 300 General Services Area (DOE, 1996).
- Final Record of Decision for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300 (DOE, 1997).
- Cost and Performance Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300 (Ferry, 1997).
- Remedial Design Document for the General Services Area Treatment Facilities, Lawrence Livermore National Laboratory Site 300 (Rueth et al., 1998).
- Building 875 Inhalation Risk Mitigation Evaluation at the Central GSA at Lawrence Livermore National Laboratory Site 300 (DOE, 2000b).
- Eastern GSA Treatment Facility Operations Checklist (LLNL, 1999).

- Operations and Maintenance Manual, Volume VI: Central General Services Area Vapor and Ground Water Treatment Facilities (Daily, 2004).
- Five-Year Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300 (Ferry, 2001).
- Quarterly Compliance Monitoring Reports for the Eastern GSA Ground Water Extraction and Treatment System (Lamarre/Yow, 2003-2005).
- Semi-annual Site-Wide Compliance Monitoring Reports that include evaluations of remediation progress in the Central GSA (Dibley et al., 2004-2005). This five-year review evaluates subsurface contaminant concentration and remediation system performance data collected through calendar year 2005.

A notice informing the public that this five-year review was in progress was placed in the Tracy Press on August 2006. The completed report will be placed in the information repositories in the Visitor's Center at the LLNL Livermore Site and at the Tracy Public Library. Notice of its completion will be placed in the Tracy Press and local contacts will be notified by letter.

7. Five-Year Review Findings

7.1. Interviews and Site Inspection

Interviews or a site inspection are not required for sites with an ongoing presence. "Ongoing presence" means that either the U.S. EPA, the State, or another agency is the lead agency for the site and that the lead agency is involved in and knowledgeable of site activities, issues, concerns, and status. Specifically, there should be regular activity at the site, evidenced by continuing response work that is overseen by the continued presence of the lead agency or regular inspections by the lead agency.

Because the cleanup at the GSA falls within the definition of "ongoing presence" neither interviews nor a site inspection were required. However, the EPA conducted a Remedial Action Construction Completion inspection on July 13, 2005. All remedial components were determined to be operational and functional.

7.2. Changes in Cleanup Standards and To-Be-Considered Requirements

There have been no changes in location-, chemical-, or action-specific requirements since the Final ROD for the GSA OU was signed in 1997.

7.3. Changes in Exposure Pathways, Toxicity, and Other Contaminant Characteristics

There have been no changes in exposure pathways, toxicity, and other contaminant characteristics since Final ROD for the GSA OU was signed in 1997.

7.4. Data Review and Evaluation

The effectiveness and protectiveness of the GSA OU remedy was assessed by reviewing contaminant mass removal data, concentration reduction trends over time, changes in VOC plume size and extent, and extraction system capture zones. The following sections include estimates of the preremediation mass of subsurface contaminants and compares these estimates to the mass of contaminants removed by ground water and soil vapor extraction. The estimates of VOC mass removed is carefully tracked and reported in the semi-annual compliance monitoring reports. However, the estimates of the preremediation mass of contaminants in the subsurface are presented assuming an uncertainty of $\pm 30\%$.

7.4.1. Central GSA

7.4.1.1. Ground Water

The original mass of VOCs estimated to have been present in the ground water in the Central GSA prior to the beginning of extraction (1993) was 25-47 kg. Since then, 13.5 kg of VOCs have been removed by ground water extraction, representing 28-54% of the original mass. Over 12.4 million gallons of contaminated ground water have been extracted and treated. TCE comprises approximately 90% of the extracted VOCs, PCE 5%, and other VOCs (Freon 113, 1,1-DCE, and 1,2-DCE) make up the remainder. The cumulative mass of VOCs extracted over time is shown on Figure 8. Figure 9 shows the mass of VOCs extracted each quarter since 1993. There has been a general decline in the rate of mass removal since remediation began. Mass removal is typically highest between January and July, when more ground water is available as a result of the infiltration of winter precipitation. Currently, approximately 0.4 kg of VOCs are extracted in ground water each year. Future mass removal rates are extremely difficult to predict because: (1) removal efficiency varies as a result of fluctuating ground water elevation and contaminant concentration, (2) changes in extraction well configuration affect removal rate, and (3) the mass removal rate will continue to decline as VOCs are removed from high-permeability sediments and diffuse slowly out of fine-grained materials.

Prior to remediation, the maximum total VOC concentration in Central GSA ground water was approximately 272,000 $\mu\text{g/L}$ (1992), compared to the current (2005) maximum of 547 $\mu\text{g/L}$. Figure 10 is an isoconcentration contour map of total VOCs in the Qt-Tnsc₁ HSU in the Central GSA constructed using second semester 2005 data. VOC concentrations have decreased throughout the contaminant plume. The number of wells in the Qt-Tnsc₁ HSU in which VOC concentrations exceed the MCL cleanup standard had decreased from 28 to 19 at the time of the 2001 Five-Year Review. By second semester 2005, this number has been further reduced to only 15 wells with VOC concentrations exceeding the MCL cleanup standard.

Figure 11 presents time-series graphs of total VOC concentrations in the following three extraction well areas: (a) the Building 875 dry well pad area, (b) the W-70 area (immediately east of the dry well pad area), and (c) the Building 872/873 dry well (W-873-07/W-872-02) area (immediately west of the dry well pad area). As shown in Figure 11, the dry well pad area is represented by well W-875-07 and shows VOC concentrations decreasing from a preremediation maximum of 107,000 $\mu\text{g/L}$ to the current 382.5 $\mu\text{g/L}$. Well W-70 shows VOC concentrations decreasing from a preremediation maximum of 752 $\mu\text{g/L}$ to the current 87 $\mu\text{g/L}$. Wells

W-873-07 and W-872-02 show VOC concentrations decreasing from preremediation maximums of 169.7 µg/L and 122.8 µg/L, respectively to current concentrations of 22.3 µg/L and 23.8 µg/L, respectively. Adjustment of the pumping rates for wells W-873-07 and W-872-02 may be considered in the near future, to increase contaminant capture and mass removal.

The results of a capture zone analysis for the existing ground water extraction wells in the Central GSA are shown on Figure 12. The capture zones were determined from the ground water elevation map based on water levels measured during pumping. This analysis shows that the capture zones include the primary contaminant release locations and areas of highest VOC concentration. New extraction wells W-7R and W-7P are included in this capture zone analysis. It should be noted that the capture of W-7P is limited to the area immediately surrounding W-7P. This well is being pumped at a very low rate in order to prevent possible inducement of a downward gradient in the Tnbs₁ HSU in this area.

Figure 13 presents time-series graphs of total VOC concentrations in four key wells in the northern plume area. No active remediation of the VOC plume has been conducted in this area. VOC concentrations in wells W-875-01, W-875-06 and W-876-01 have decreased from historical maximums of 211.4 µg/L, 46.9 µg/L, and 75.2 µg/L, respectively to current (2005) concentrations of 24.6 µg/L, 0.87 µg/L, and 1.8 µg/L, respectively. VOC concentrations increased in W-889-01 to a historical maximum of 75 µg/L in April 1998, but has since decreased to a current (2005) concentration of 35.85 µg/L. The concentration trend for W-889-01 suggests that an additional source influx may have occurred in this area in the mid- to late-1990s. Well W-889-01 may be considered for conversion to an extraction well in the future if contaminant concentrations increase.

Low concentrations of VOCs are present in shallow Tnbs₁ ground water in the eastern portion of the Central GSA. Since the last five-year review, VOCs have been detected in only 4 of the 15 wells screened in the Tnbs₁ regional aquifer. VOC concentrations in Tnbs₁ ground water have decreased from a historical maximum of 63 µg/L to 9 µg/L in the fourth quarter of 2005. TCE concentrations exceed the MCL cleanup standard in only one Tnbs₁ well.

Without additional actions, it is expected that future compliance with ground water cleanup standards will be achieved. The performance of the selected remedy in the Central GSA is generally consistent with modeling performed in the Remedial Design that estimated the time to reach cleanup standards would be approximately 30 years (i.e., by 2027).

7.4.1.2. Vadose Zone

Soil vapor extraction has been significantly more effective than ground water extraction in removing VOC mass from the subsurface. The original mass of VOCs estimated to have been present in the vadose zone in the Central GSA prior to the beginning of extraction (July, 1994) was 73 to 136 kg. Since then, 66.72 kg of VOCs have been removed by soil vapor extraction, representing 49-91% of the original mass. The extracted VOCs are comprised almost exclusively of TCE. The cumulative mass of VOCs extracted over time is shown on Figure 8. Figure 9 shows the mass of VOCs extracted each quarter since 1994. The rate of mass removal is extremely variable, possibly as a result of: (1) temporal permeability variations in the subsurface caused by changes in vadose zone moisture content, (2) seasonal changes in the thickness of the vadose zone from fluctuating ground water levels, and/or (3) changes in the VOC concentration in extracted soil vapor as the extraction and air injection well configuration

is changed. Currently, approximately 0.8 kg of VOCs are extracted in soil vapor each year. The future rate of VOC mass removal by soil vapor extraction is even more difficult to predict than that for ground water extraction.

In order to evaluate the magnitude of remaining TCE source, a soil vapor rebound test was conducted from December 2003 to October 2004. The rebound test consisted of shutting down vapor extraction for 10 months while monitoring the rebound of vapor concentrations in individual extraction wells. Table 2 presents soil vapor treatment facility influent and soil vapor extraction well data used to interpret the rebound test including: (1) the historical maximum TCE concentration, (2) the diffusion-limited TCE concentration prior to the rebound test, and the maximum TCE concentration observed during the rebound period. As shown in Table 2, the TCE concentration in the soil vapor system influent decreased from a historical maximum of 417 ppm_{v/v} six months after startup of SVE (January 1995) to a maximum concentration of 0.3 ppm_{v/v} prior to system shutdown for the rebound test in December 2003. Following the 10-month rebound period, the maximum TCE concentration detected in the facility influent was 1.1 ppm_{v/v} suggesting a significant decrease in magnitude of the TCE source. Maximum influent concentrations following previous SVE shutdowns ranged between 270 and 1.1 ppm_{v/v} and have consistently decreased over time.

The TCE concentrations in soil vapor measured in individual extraction wells screened primarily in the Tnbs₂ sandstone decreased from historical maximums ranging from 58 ppm_{v/v} to 529 ppm_{v/v} to pre-rebound test concentration ranges of 0.6 ppm_{v/v} to 2.8 ppm_{v/v} (Table 2). These low vapor concentrations are indicative of diffusion-limited conditions. Following the rebound test, the maximum TCE concentrations observed in the extraction wells ranged from 6 ppm_{v/v} to 29 ppm_{v/v}. Although some rebound of VOCs in soil vapor occurred, this data indicate that soil vapor extraction has been successful in reducing VOC mass in the Tnbs₂ sandstone.

TCE in soil vapor in Tnsc₁ extraction well W-7I decreased from a historical maximum concentration of 200 ppm_{v/v} to a diffusion-limited TCE concentration of 2.8 ppm_{v/v} prior to system shutdown for the rebound test. During the rebound period, TCE increased significantly to a concentration of 316 ppm_{v/v} in soil vapor in well W-7I. Well W-7I is screened in the low-permeability Tnsc₁ claystone/siltstone, while the other soil vapor extraction wells are screened primarily in the overlying more permeable Tnbs₂ sandstone. The significant rebound of TCE soil vapor concentrations in well W-7I indicates that TCE mass remains in the low-permeability Tnsc₁ claystone/siltstone. In November 2005, a test of individual well vapor flow rates indicated no flow from well W-7I, and this well has been discontinued as an SVE well. The persistence of high concentrations in W-7I and the observed low flow rate indicates that the formation (Tnsc₁) in the immediate vicinity of this well exhibits very low pneumatic permeability.

The performance of the soil vapor extraction system is generally consistent with modeling performed in the Remedial Design (Rueth et al, 1998) that estimated the time to reach cleanup standards would be approximately 20 to 25 years (i.e., by 2015 to 2020). Soil vapor extraction has contributed to reducing the excess cancer risk due to inhalation of VOC vapors migrating into Building 875 from 1×10^{-5} prior to remediation to 9.5×10^{-7} in 2000. Inhalation risk within Building 875 is no longer of concern.

Future optimization of the Central GSA vapor treatment system will include:

1. Additional rebound testing to evaluate source magnitude.
2. Periodic reconfiguration of extraction versus inlet wells to optimize mass removal.
3. Installation of individual vapor flow meters to more accurately track flow and mass removal from individual wells.

7.4.2. Eastern GSA

The original mass of VOCs estimated to have been present in the ground water in the Eastern GSA prior to the beginning of extraction (1991) was 0.5 to 2.3 kg. Since then, approximately 7.1 kg of VOCs have been removed by ground water extraction. The mass of VOCs extracted exceeds the preremediation estimate because: (1) ground water with higher VOC concentration than is represented by samples from monitor wells is present, resulting in an artificially low estimate of initial mass, and/or (2) undetected VOC mass is present in the vadose zone, although site characterization indicated that the VOC concentrations in unsaturated soil and bedrock are extremely low.

Over 267 million gallons of contaminated ground water have been extracted and treated. The extracted VOCs are comprised almost exclusively of TCE. The cumulative mass of VOCs extracted over time is shown on Figure 8. Figure 9 shows the mass of VOCs extracted each quarter since 1991. There has been a general decline in the rate of mass removal since remediation began. Mass removal is relatively consistent throughout the year. Approximately 0.13 kg of VOCs is extracted in ground water each year.

Recent data (2nd Semester 2005) indicate that remediation of Eastern GSA ground water has successfully reduced concentrations of TCE and other VOCs to below their MCL cleanup standards in all wells. Since extraction and treatment began at the Eastern GSA in 1991, TCE concentrations in ground water have decreased from a historical maximum of 74 $\mu\text{g/L}$ to below analytical detection limits (0.5 $\mu\text{g/L}$) in the majority of wells. The number of wells in which TCE concentrations exceed the MCL cleanup standard has decreased from 18 to 0. Figure 14 is an isoconcentration contour map of total VOCs in the shallow aquifer in the Eastern GSA constructed using 2005 data. Figure 15 is a set of time-series maps showing changes in the extent and concentrations of TCE in ground water in the Eastern GSA. The length of the TCE plume in ground water at concentrations exceeding detection limits has been reduced from 4,200 ft to 350 ft, and the portion of the plume exceeding 5 $\mu\text{g/L}$ has been eliminated. The performance of the selected remedy in the Eastern GSA is generally consistent with modeling performed in the Remedial Design phase that estimated the time to reach cleanup standards would be approximately 10 years (i.e., by 2008).

For this reason, DOE/LLNL has proposed to initiate the “Requirements for Closeout” described in the Remedial Design for the GSA Operable Unit (OU) (Rueth et al., 1998). These requirements specify that “when VOC concentrations in ground water have been reduced to cleanup standards, the ground water extraction and treatment system will be shut off and placed on standby.” As required, ground water monitoring will be conducted to determine if VOC concentrations rise or “rebound” above cleanup standards after extraction ceases. No additional action is expected to be required to achieve cleanup standards unless monitoring indicates that VOC concentrations rebound.

8. Technical Assessment

The protectiveness of the remedy was assessed by determining if:

- The remedy is protective of human health and the environment.
- The remedy is functioning as intended by the decision documents.
- The exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of the remedy selection are still valid.
- Any other information has come to light that could call into question the protectiveness of the remedy.

This five-year review determined that the remedy for the GSA OU was protective and effectively functioning as intended in the decision documents, based on the following:

- Ground water and soil vapor extraction are effectively reducing contaminant concentrations in the subsurface. In the Central GSA, the current maximum VOC concentrations in both ground water and soil vapor have decreased by over two orders of magnitude. VOC concentrations throughout the ground water plume have declined. In the Eastern GSA, VOC concentrations in ground water have been reduced to below the MCL cleanup standard.
- DOE has removed a total of 87.4 kg of VOCs from the subsurface in the GSA OU. This represents 47-88% of the estimated preremediation mass of total VOCs present in the subsurface. Mass removal rates are declining for both ground water and soil vapor as contaminants are removed from more permeable subsurface sediment and diffuse slowly from low-permeability materials.
- Overall performance of the selected remedy in the GSA OU is consistent with expectations at the time the ROD was signed. The Central GSA extraction and treatment systems are performing as designed and will continue to be operated and optimized.
- Ground water remediation in the Eastern GSA has successfully reduced concentrations of TCE and other VOCs to below their drinking water MCL cleanup standards. Therefore, DOE/LLNL proposes to shut off the ground water extraction and treatment system and monitor ground water to determine if VOC concentrations rise or “rebound” above cleanup standards after extraction ceases.
- System operation procedures are consistent with requirements.
- Costs have been consistently within budget.
- No early indicators of potential remedy failure were identified.
- All required institutional controls are in place.
- The Contingency Plan and the Health and Safety Plan are in place, sufficient to control risks, and properly implemented.

This five-year review for the GSA OU determined that the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of the remedy selection are still valid, based on the following:

- There have been no changes in location-, chemical-, or action-specific requirements since the ROD for the GSA OU was signed in 1997, nor have there been changes in exposure pathways, toxicity, and other contaminant characteristics.
- There have been no changes in risk assessment methodologies that could call the protectiveness of the remedy into question.
- Soil vapor extraction at the Building 875 release site has contributed to reducing the human health risk due to inhalation of TCE vapors within nearby Building 875 to a level that is not of further concern. In September of 2000, DOE submitted the Building 875 Inhalation Risk Mitigation to the EPA, DTSC, and RWQCB. The report provided data that demonstrated that the remediation systems in the Central GSA had reduced the VOC inhalation risk inside Building 875 to below 1×10^{-6} , the level designated by EPA as protective of human health.
- There are no planned changes in land use at the site or planned modification or proposed development of the offsite land adjacent to the GSA.

This five-year review for the GSA OU determined that no other information has come to light that calls into question the protectiveness of the remedy, based on the following:

- There are no new ecological risks, natural disaster impacts, or any other new information that could call into question the protectiveness of the remedy.
- No new contaminants, source areas, or remedy by-products have been found in the GSA OU since the previous five-year review.

In summary, the remedy is functioning as intended, the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of the remedy are still valid, and no new information has come to light that calls into question the protectiveness of the remedy.

9. Deficiencies

No deficiencies were identified during the five-year review process.

10. Recommendations and Follow-Up Actions

The following recommendations to be carried out by the DOE were developed during the five-year review process:

1. Because cleanup standards (MCLs) have been achieved in Eastern GSA ground water, DOE/LLNL proposes to shutoff the ground water extraction and treatment system and monitor ground water to determine if VOC concentrations rebound above cleanup standards after extraction ceases. Ground water in the Eastern GSA will be monitored for a period of five years following shutdown of the ground water extraction and treatment system. Should VOC concentrations in ground water increase above cleanup standards, reinitiation of remediation efforts will be discussed with the EPA, DTSC, and RWQCB. The ground water system will be restarted and operated until cleanup standards are

achieved, unless DOE and the regulatory agencies agree otherwise. Several pumping cycle iterations may be required to achieve the cleanup standards.

2. Further optimization of Central GSA wells W-872-02 and W-873-07 operations should be considered. This may include repositioning the pumps in these wells and/or changing the pumps in order to increase ground water yield, capture, and contaminant mass removal.
3. VOC concentrations in Central GSA well W-889-01 (in the northern plume area) should be closely monitored. If concentrations increase, this well should be considered for conversion to an extraction well.
4. Optimization of the Central GSA SVE system should continue. Future optimization should include additional rebound testing to evaluate source magnitude, periodic reconfiguration of extraction versus inlet wells to optimize mass removal, and installation of individual vapor flow meters to more accurately track flow and mass removal from individual wells.

No other follow-up actions were identified related to this five-year review.

11. Protectiveness Statement

The Health and Safety Plan and the Contingency Plan are in place, sufficient to control risks, and properly implemented. Ground water and soil vapor extraction and treatment are effectively controlling the migration of contaminants, and are reducing contaminant concentrations in the subsurface as needed to meet cleanup standards in the time frame anticipated at the time of the ROD. Institutional controls are in place to prevent use of contaminated ground water. Thus, the remedy for the GSA OU is protective of human health and the environment.

12. Next Review

The next policy review will be conducted within five years of the signature date of this report.

13. References

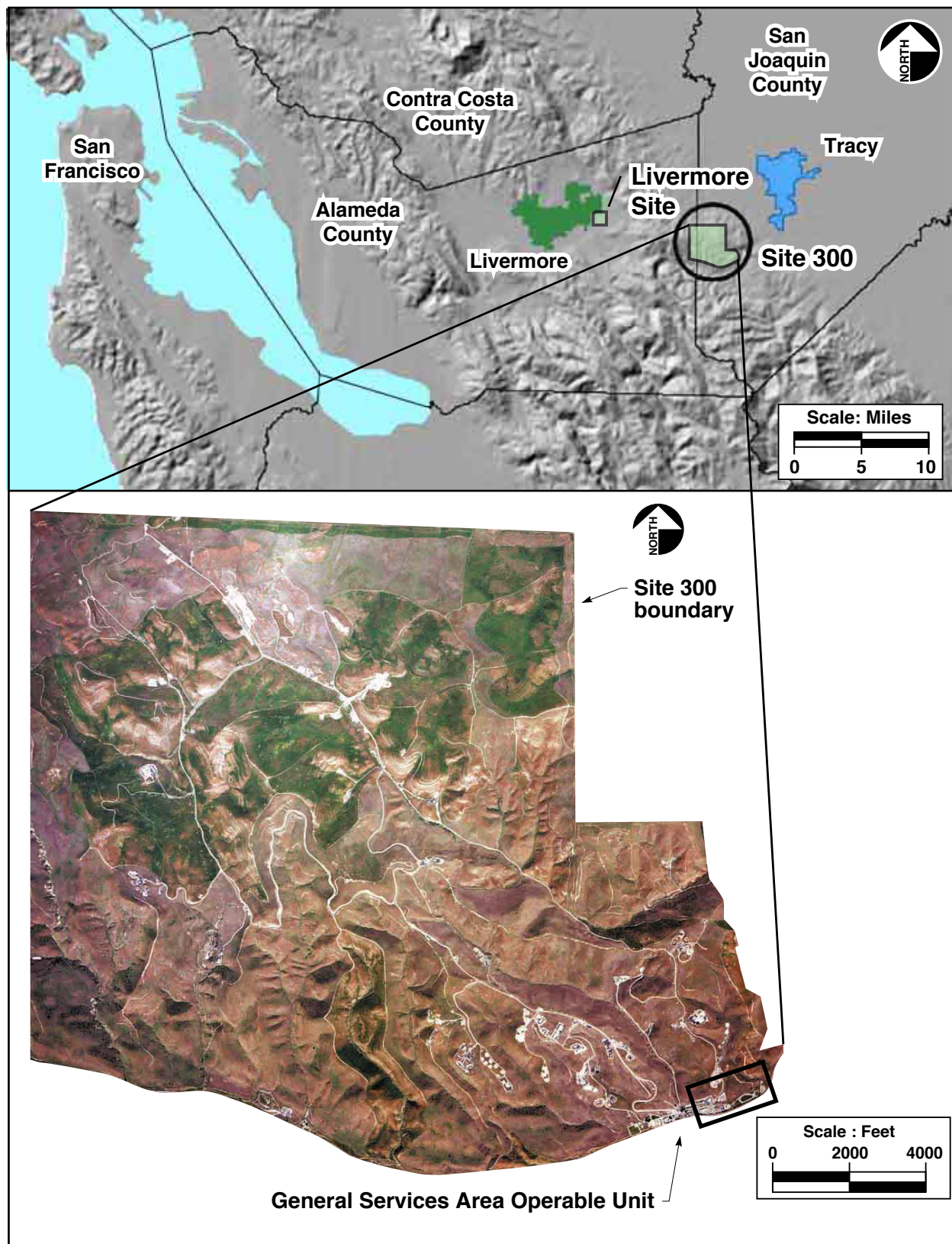
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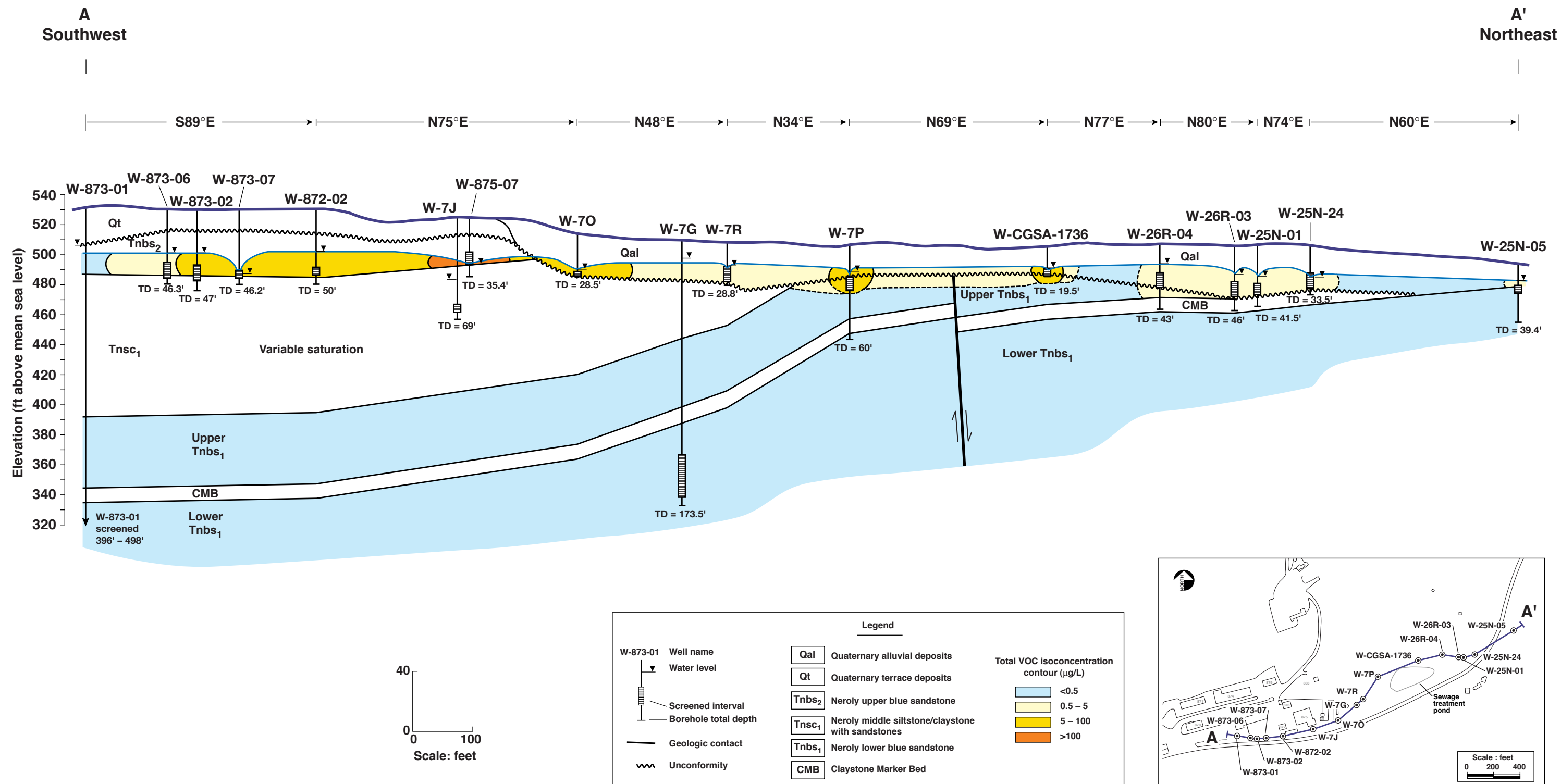
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Figures



ERD-S3R-06-0014

Figure 1. Locations of LLNL Site 300 and the GSA OU.



ERD-S3R-06-0005

Figure 2. Hydrologic cross-section of the General Services Area.

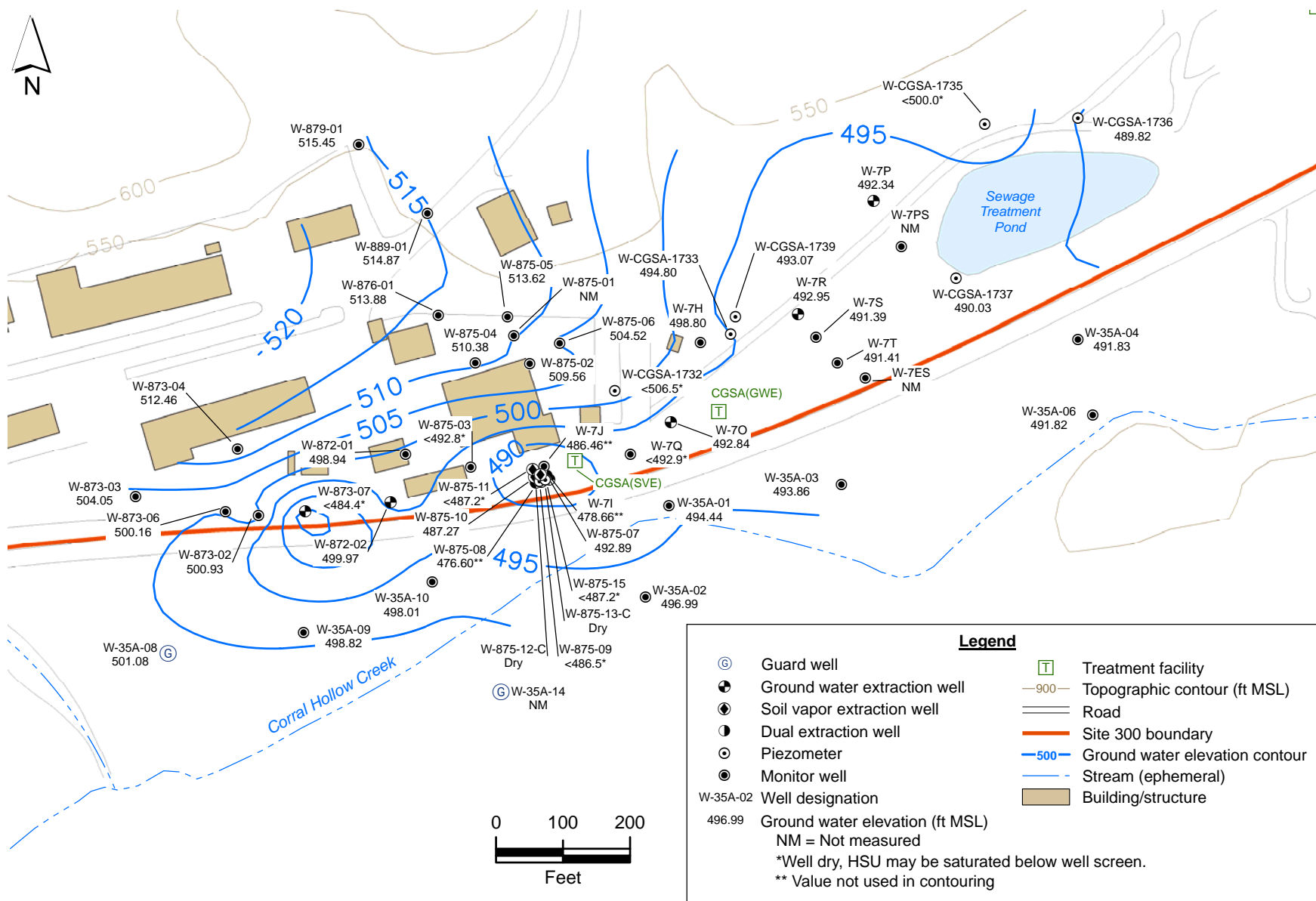


Figure 3. Potentiometric surface of the Qt-Tnsc₁ and Qal-Tnbs₁ HSUs in the Central GSA.

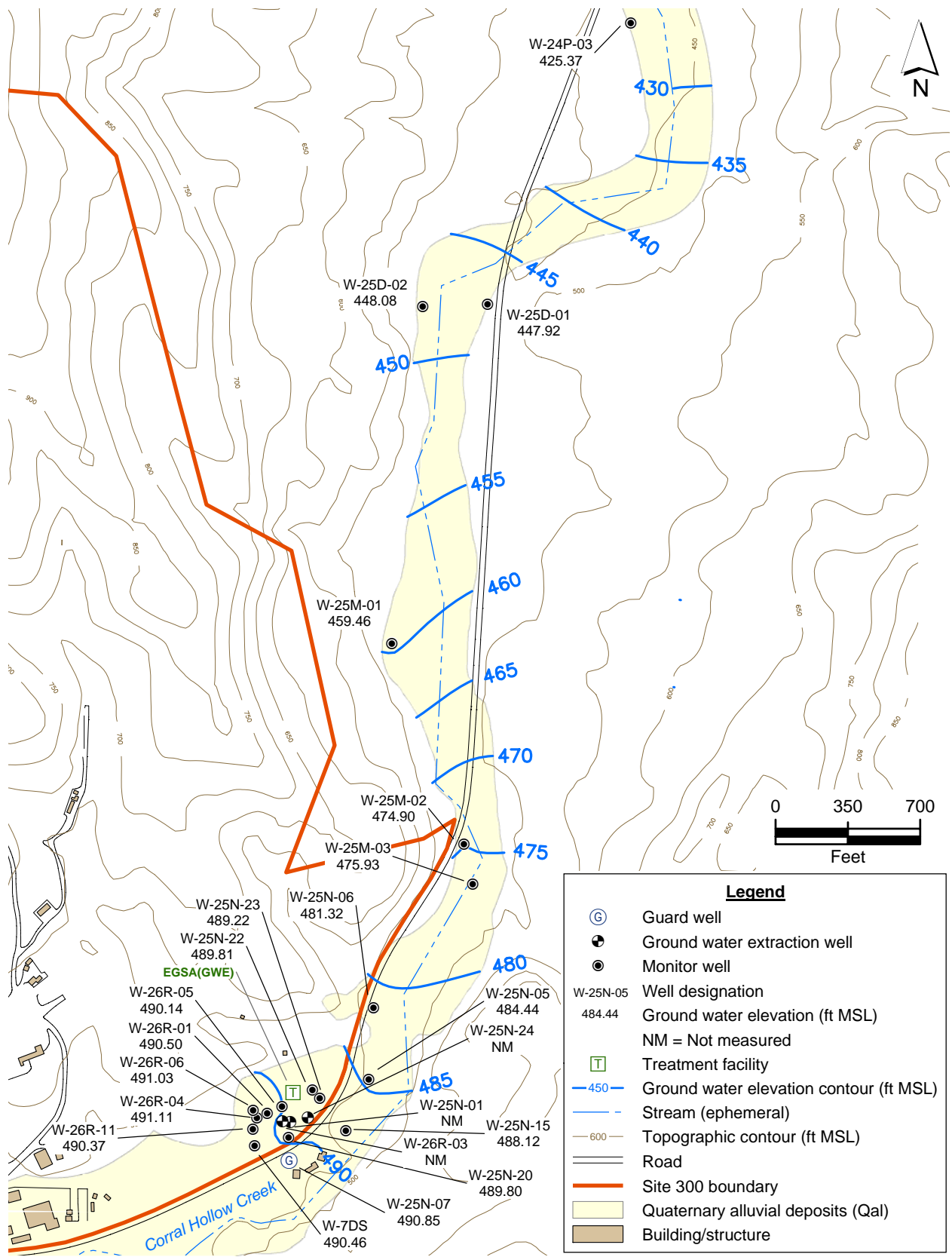


Figure 4. Potentiometric surface of the Qal-Tnbs₁ HSU in the Eastern GSA.

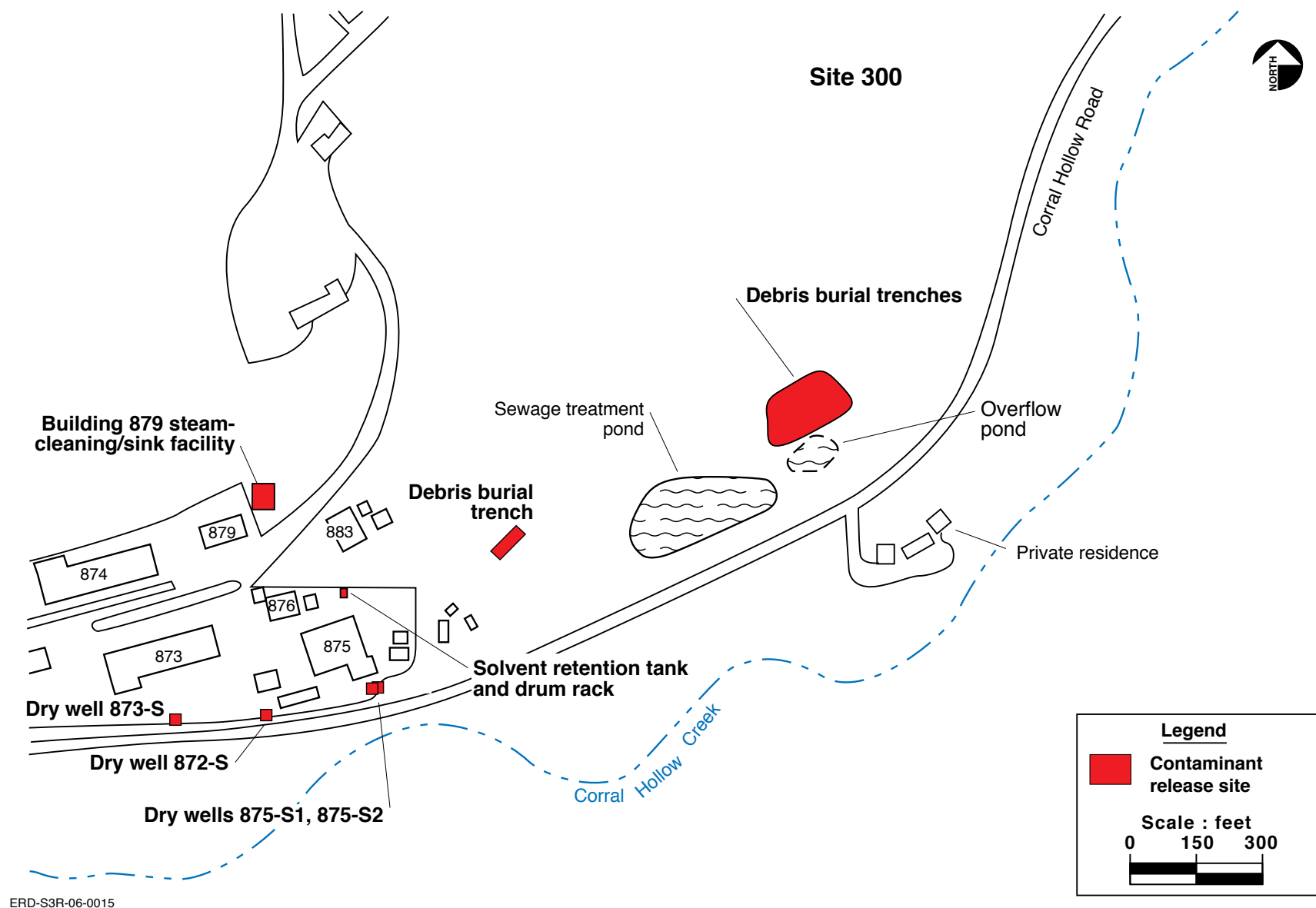


Figure 5. Contaminant release sites in the GSA.

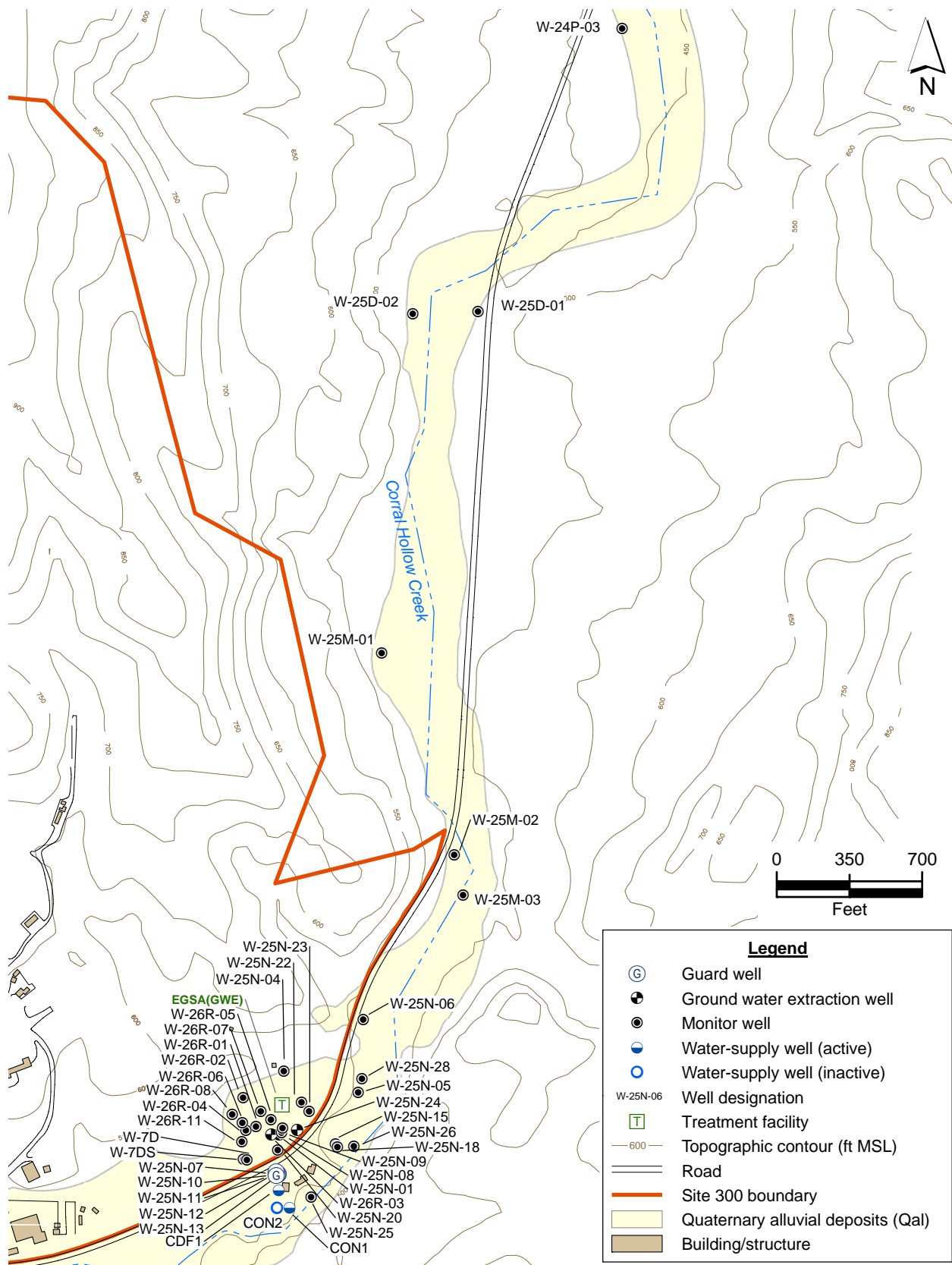
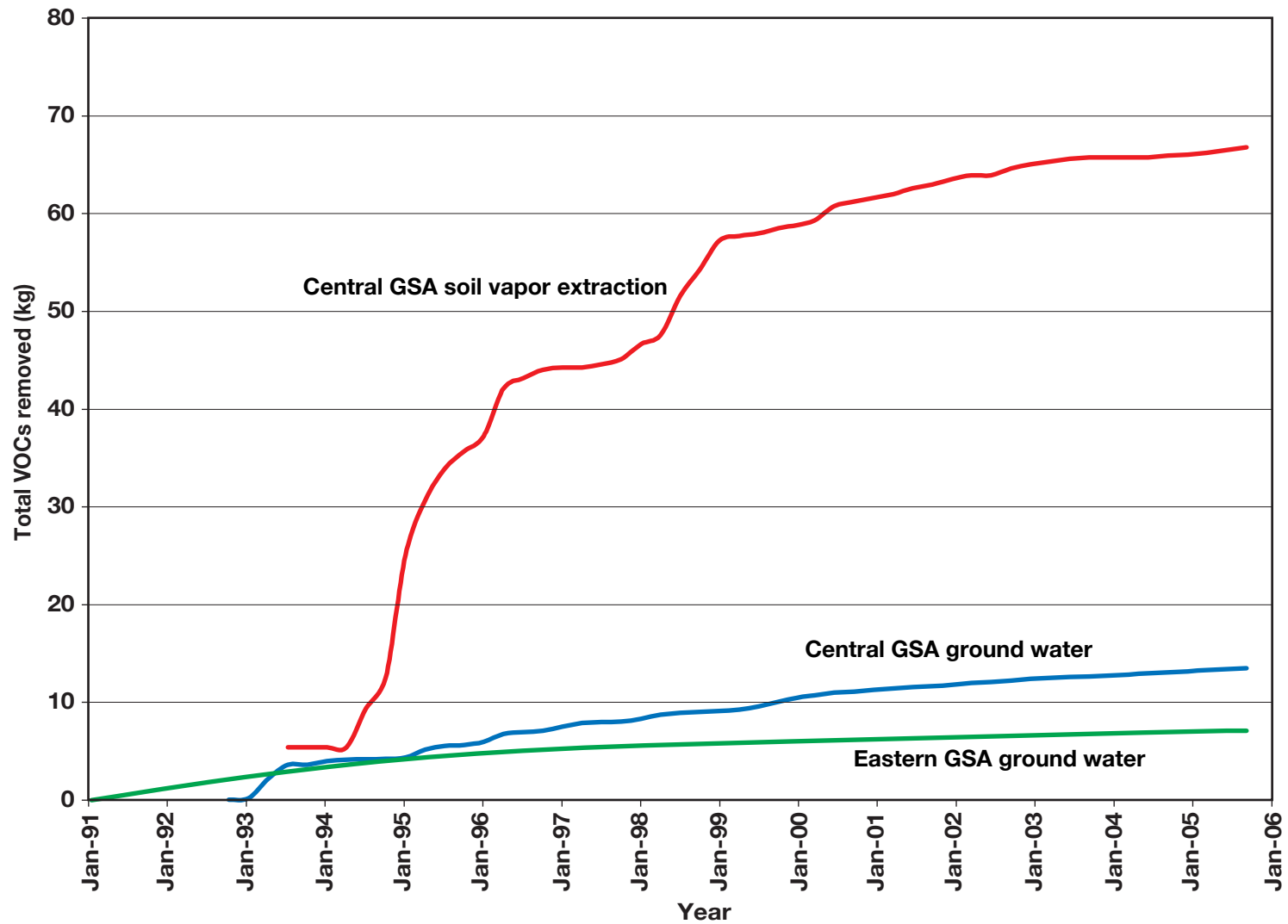
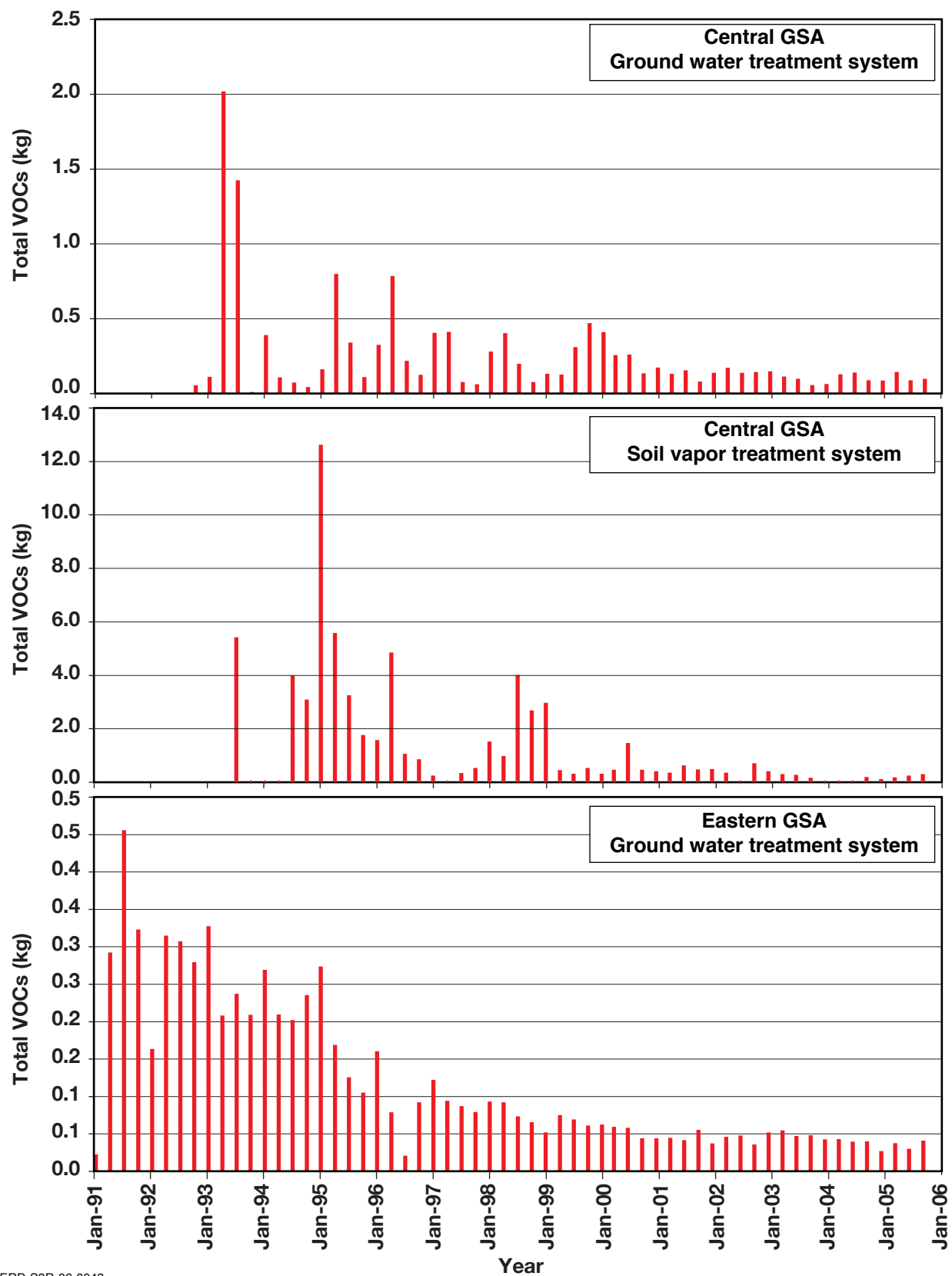


Figure 7. Eastern General Services Area site map showing monitor, extraction, and water-supply wells, and treatment facilities.



ERD-S3R-06-0042

Figure 8. Cumulative mass of total VOCs removed from ground water and soil vapor in the GSA.



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Figure 9. Total VOC mass removal by quarter in the GSA OU.

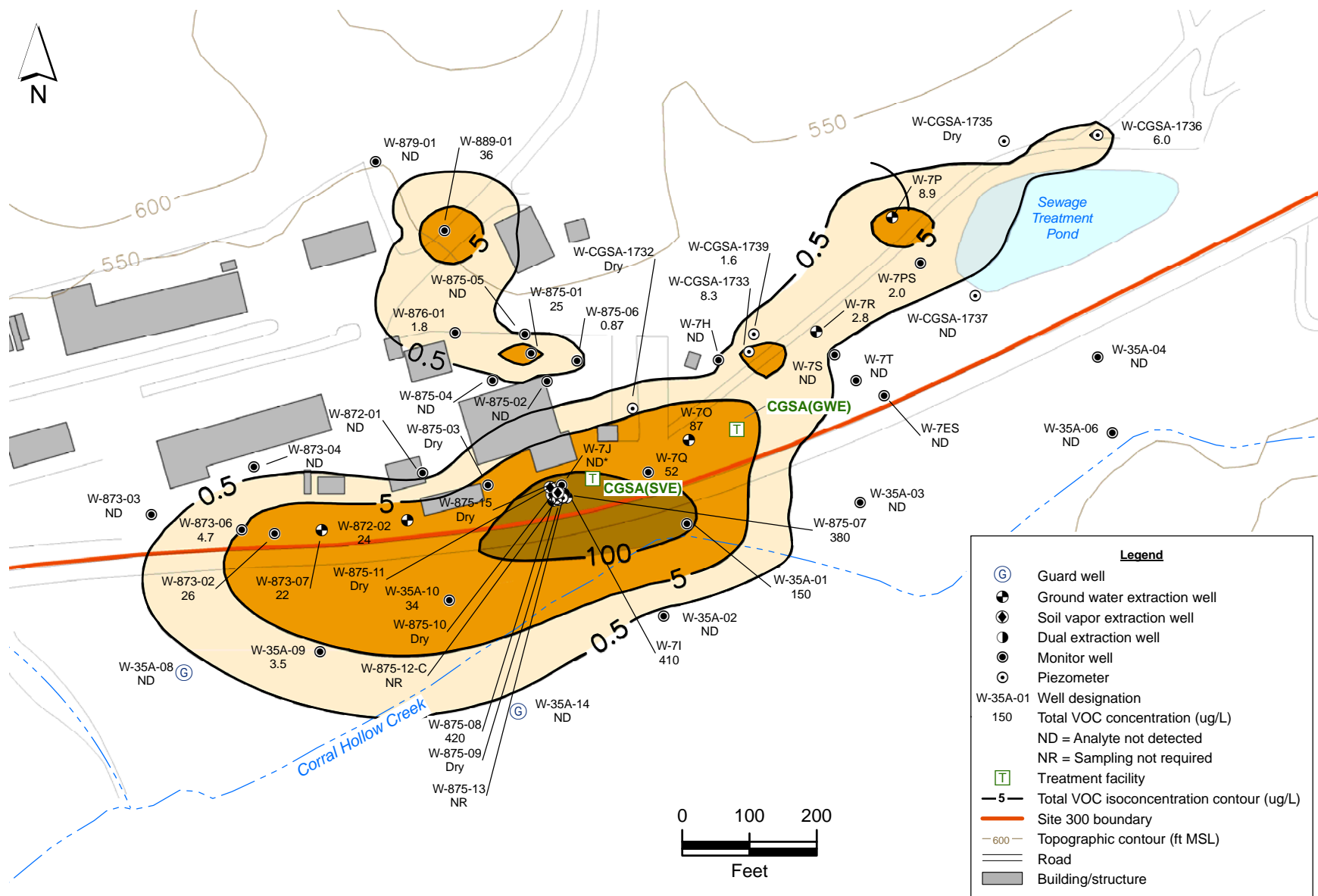


Figure 10. Total VOC concentrations in ground water in the Qt-Tnsc₁ and Qal-Tnbs₁ HSUs in the Central GSA.

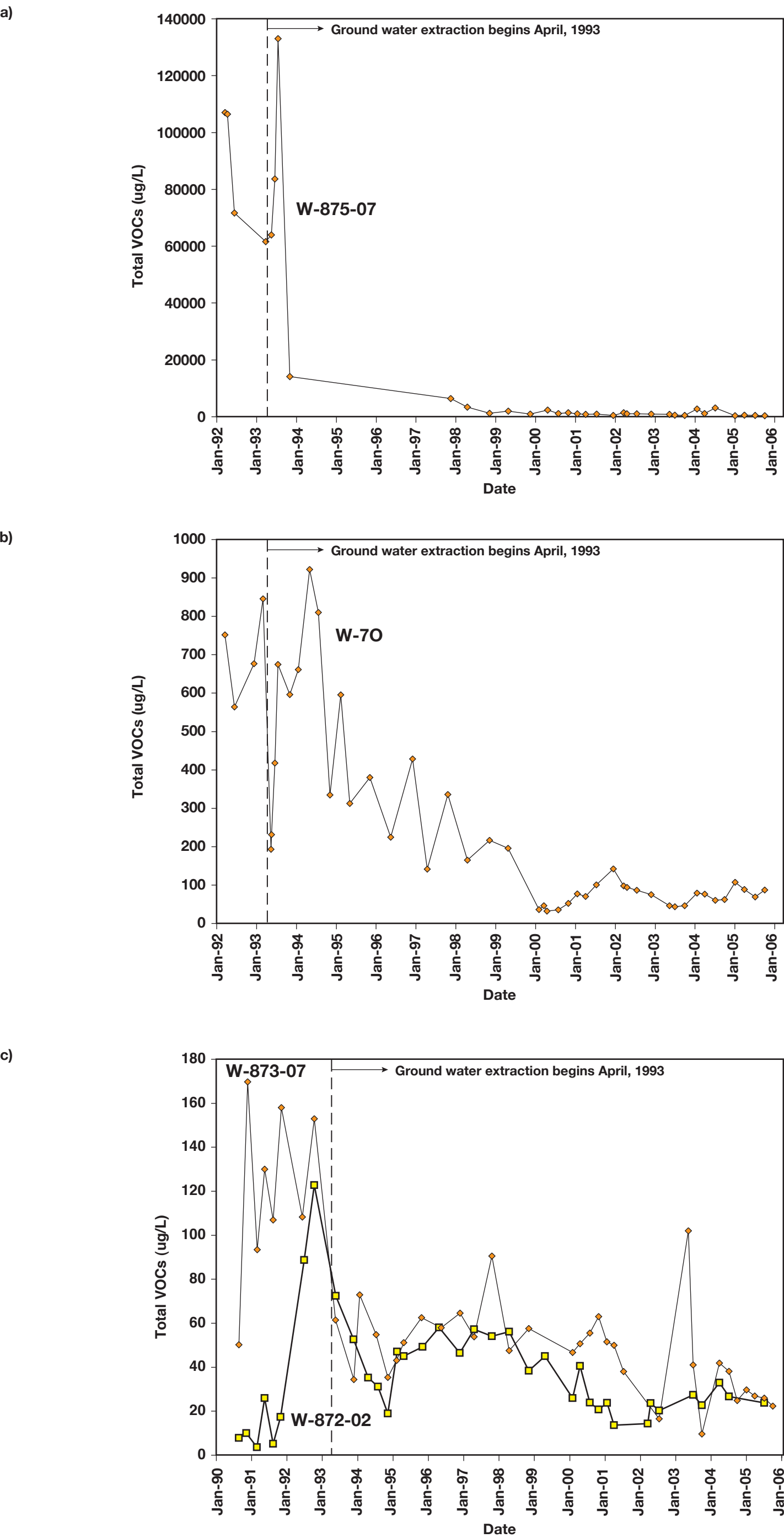


Figure 11. Time-series graphs of total VOCs in ground water for Central GSA extraction wells a) W-875-07 (Building 875 dry well pad area), b) W-70, and c) W-873-07/W-872-02.

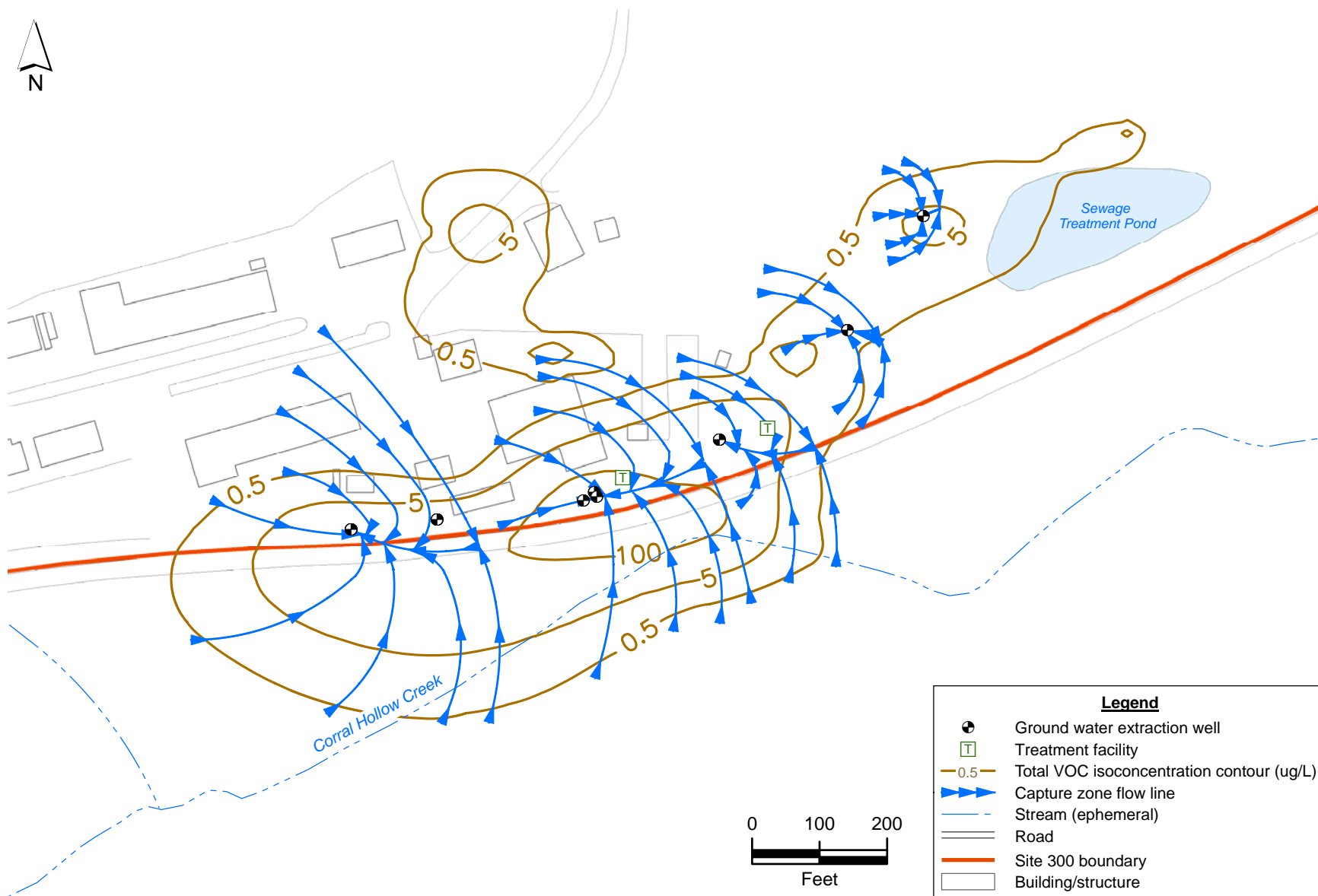
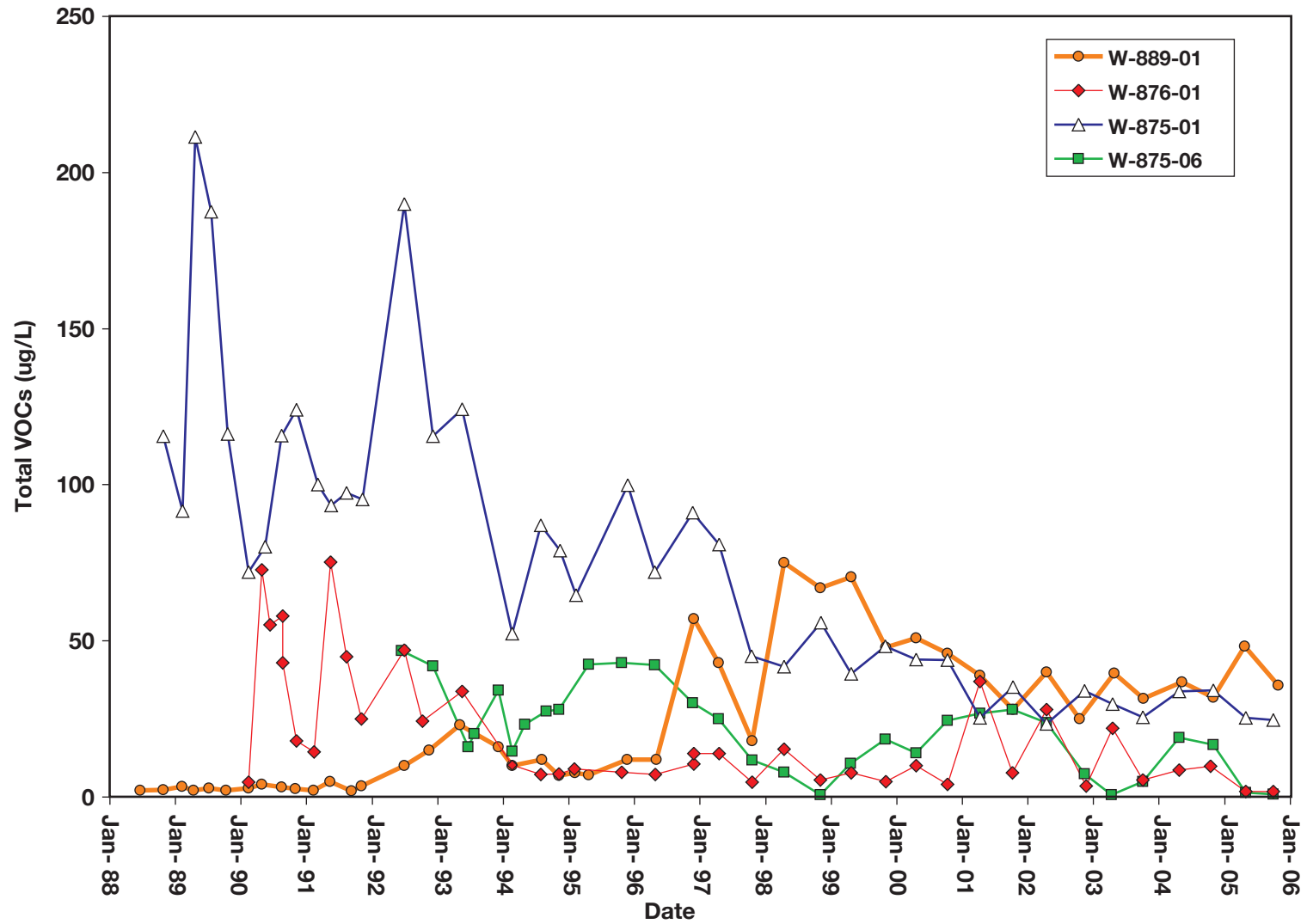


Figure 12. Ground water capture in the Central GSA.



ERD-S3R-06-0026

Figure 13. Time-series graphs of total VOCs in ground water for wells in the Central GSA northern plume area.

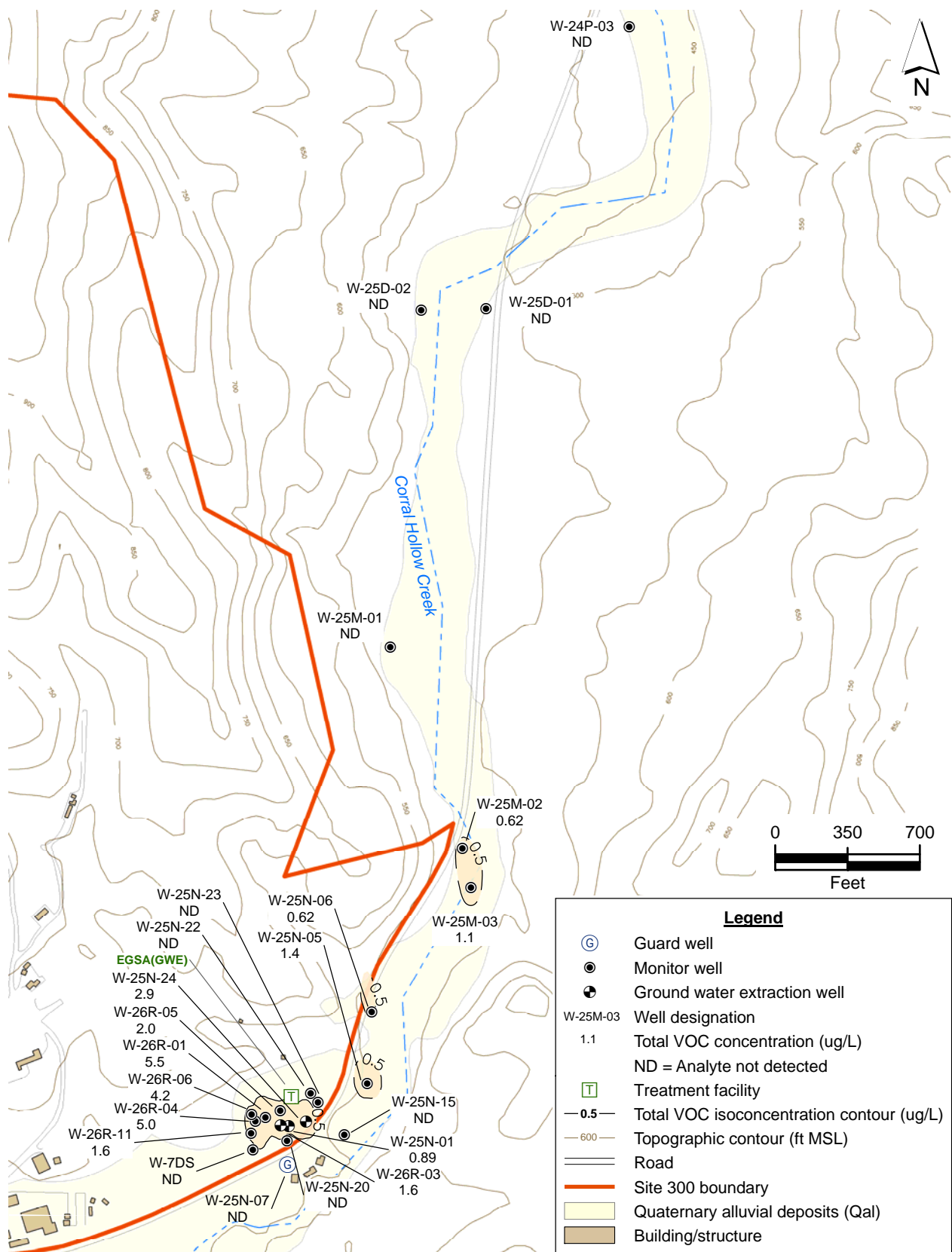


Figure 14. Total VOC concentration in groundwater in the Qal-Tnbs₁ in the Eastern GSA and vicinity.

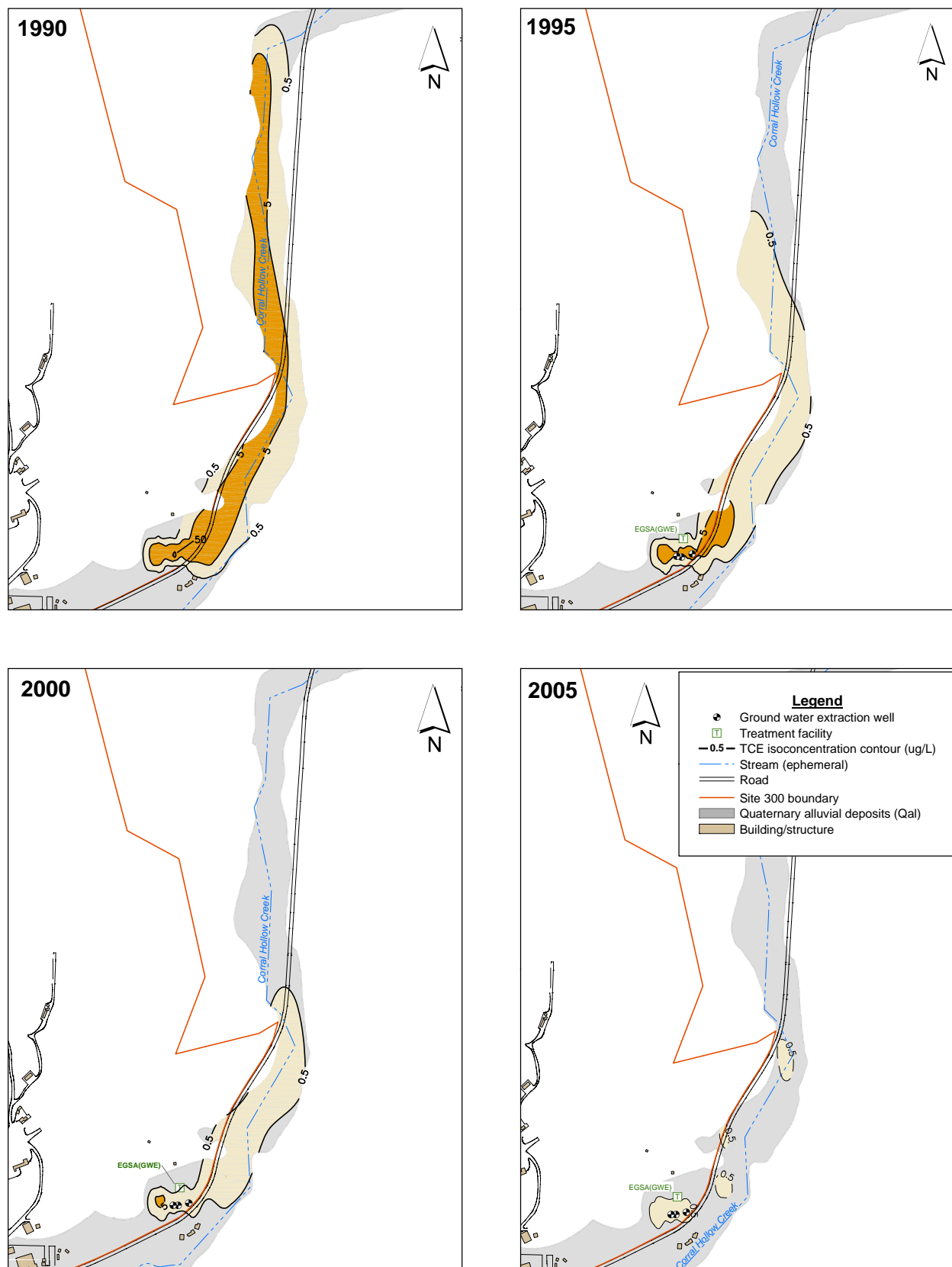


Figure 15. Time-series isoconcentration maps of TCE in ground water in the Eastern GSA.

Tables

Table 1. Actual annual costs for the General Services Area Operable Unit for fiscal years 2001 through 2005.

Fiscal year	Annual budget	Actual annual cost
2001	\$581,408	\$482,788
2002	\$582,081	\$376,723
2003	\$351,855	\$436,654
2004	\$351,369	\$344,792
2005	\$430,131	\$431,000

Table 2. Summary of trichloroethylene (TCE) data used to evaluate Central GSA Soil Vapor Extraction (SVE) performance.

Well name	Well type	Historical maximum TCE concentration (ppm _{v/v})	Date of historical maximum	Concentration prior to rebound test (ppm _{v/v})	Rebounded maximum concentration (ppm _{v/v})	Flow ^a (scfm)
TF-GSA2-IV ^b	NA	417	1/18/95	0.3	1.1 ^c	22 ^d
W-875-07	Vapor Extraction	529	7/21/94	1.8	29	3.1
W-875-08	Vapor Extraction	249	7/25/94	1.6	12	2.8
W-875-09	Vapor Inlet	241	10/29/97	0.6	25	NA
W-875-10	Vapor Extraction	293	7/25/94	0.6	6	14
W-875-11	Vapor Inlet	58	10/29/97	1.1	6.8	NA
W-875-15	Vapor Inlet	120	10/29/97	1	14	NA
W-7I	Vapor Extraction	200	10/29/97	2.8	316	Too low to measure

Notes:

scfm = Standard cubic feet per minute.

NA = Not Applicable.

^a Flow as measured during the test conducted during November 2005.^b Influent.^c Maximum influent concentration after SVE system was re-started following rebound test (December 2004).^d Average of weekly flows of the influent for the month of November 2005.